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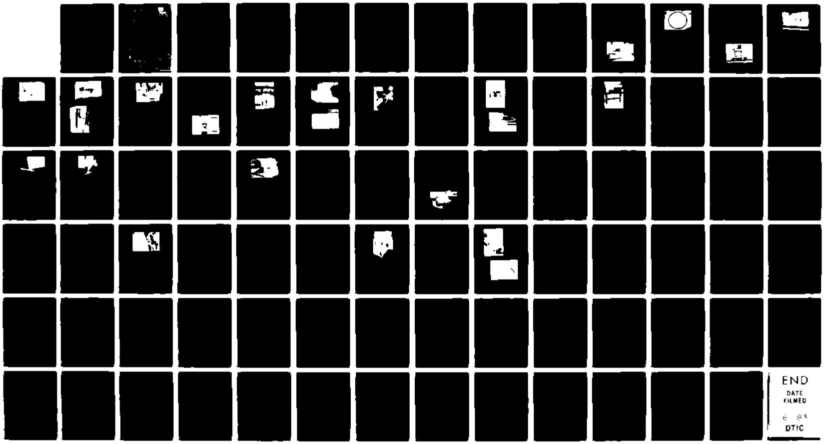

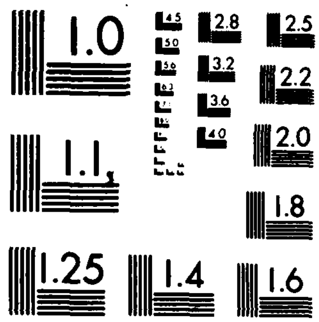

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Special Report 83-3

January 1983

The CRREL Instrumented Vehicle

Hardware and software

George L. Blaisdell

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, Metric Practice Guide, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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This report gives a detailed description of the CRREL Instrumented Vehicle (CIV). The CIV is equipped with instrumentation to measure three mutually perpendicular forces acting at the interface between the front tires and any surface material. In addition, accurate wheel and vehicle speeds and rear axle torque are measured. The vehicle is equipped for front-wheel, rear-wheel or four-wheel drive. A dual brake system allows front-, rear- or four-wheel braking. A minicomputer-based data acquisition system is installed in the vehicle to control data gathering and to process the data. The software for data acquisition and manipulation and the interfacing techniques required are described.

PREFACE

This report was prepared by George L. Blaisdell, Research Civil Engineer, of the Applied Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory. Funding was provided by DA Project 4A762730AT42, Design, Construction, and Operations Technology for Cold Regions; Technical Area A, Combat Operations Support; Work Unit 003, Battlefield Mobility in Cold Regions. The author expresses gratitude to Dr. William Harrison and Ronald Atkins for their careful technical reviews of this report.

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THE CRREL INSTRUMENTED VEHICLE: HARDWARE AND SOFTWARE

George L. Blaisdell

INTRODUCTION

Since the advent of the pneumatic tire, a sophisticated system of transportation has developed to the point where nearly all of our functions are in some way affected by vehicular transportation. For nearly a century continued efforts have been directed towards making faster, safer and more efficient vehicles. With this has come great refinements in tire technology and our understanding of vehicle mobility. However, tire design, evaluation and testing methods are still the subjects of a large number of studies and will remain so in the forseeable future. Likewise, prediction of vehicle mobility is still in its developmental stages.

The quantities of traction and motion resistance have characteristically been used to establish how mobile (or immobile) a vehicle is, especially on deformable surface materials. It is reasonable to conclude that these quantities are really measures of tire performance, provided the vehicle is adequately powered. In the past, tests to evaluate traction involved using a dynamometer (hold-back) vehicle equipped with a load-cell drawbar. Traction was then calculated from the measured drawbar pull, the motion resistance and appropriate correction factors. Motion resistance was determined from vehicle deceleration and by towing or pushing the vehicle.

Traction and motion resistance as quantities are really just measures of the forces between the vehicle's tires and their supporting surface. However, past testing measured quantities that are physically removed from the vehicle/material interface. With the development of a sophisticated load cell and a specially equipped vehicle, direct measurement of these forces is now possible.

This report will describe in detail the equipment and operation of the CRREL Instrumented Vehicle (CIV), which is equipped with these load cells. This information is meant to supplement the operation manuals provided by the manufacturers of the individual pieces of equipment (Appendix A). Points that are either omitted or not clear in these manuals and the techniques involved with operating all of the equipment together are emphasized in this report.

VEHICLE HARDWARE

The CRREL Instrumented Vehicle was originally constructed by the Nevada Automotive Test Center (NATC) in Carson City, Nevada, and is based on a 1977 AMC Jeep Cherokee frame and chassis (Fig. 1). The stock vehicle was modified by NATC in May of 1978 under contract with the San Dimas Equipment Development Center of the U.S. Forest Service, San Dimas, California. Further mechanical modifications were made to the vehicle by NATC in February of 1980 under the direction of CRREL. Subsequently, electronic modifications have been made by CRREL.

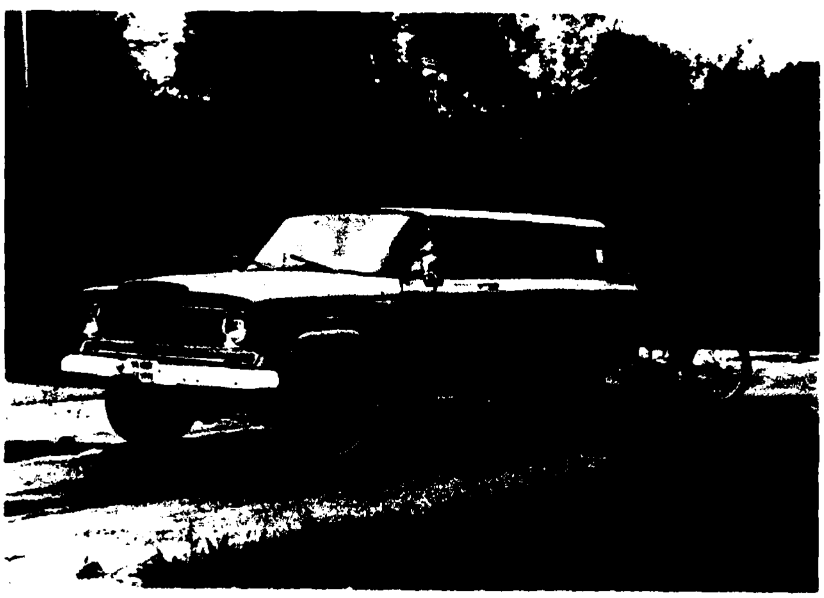


Figure 1. CRREL instrumented vehicle.

Figure 2. Warn lock-out axle.

Mechanical hardware

Special equipment was added to the vehicle to facilitate specific test configurations and to provide support for the data acquisition instrumentation. This included changes to the hubs, the transfer case, the brakes, the shock absorbers, the electrical system and the seats.

The instrumented vehicle is equipped with Warn locking hubs on all four axles (Fig. 2). This allows the vehicle to be operated as a four-wheel-drive, rear-wheel-drive or front-wheel-drive unit. This versatility is made possible by the Quadra-Trac full-time four-wheel-drive system, which was stock equipment on the vehicle before its modification. With the Quadra-Trac system, engine torque is delivered from the transmission to a controlled-slip third differential (or transfer case), which is located directly behind the transmission. The transfer case, in turn, transmits torque along front and rear propeller shafts to the differentials located between the front and rear sets of wheels. The transfer case ensures that some torque is sent to both front and rear propeller shafts. This results in drive to at least one front and one rear wheel (due to breakdown of torque at the front and rear differentials).

With all four Warn hubs locked, the vehicle operates as a normal full-time four-wheel-drive unit. It can be driven at highway speeds or used with Jeep's low-range reduction unit (gear reduction) for greater engine braking, control and torque at low vehicle speeds.

Two-wheel drive (front or rear) is not as straightforward. Since the Quadra-Trac transfer case sends torque to both propellor shafts in proportion to their needs, having two hubs (both front or both rear) in the free position causes them to appear to be most in need of torque. The transfer case thus sends all of the torque to the differential of the free axles, which produces no vehicle movement. However, the vehicle is equipped with an emergency drive system (Fig. 3), a stock item controlled by a switch in the glove box. When engaged, the system nullifies the differenti action of the transfer case. An equivalent amount of torque is then se to each propellor shaft, and two-wheel drive is achieved.

A dual-brake system has also been built into the CIV. This tem allows hydraulic pressure to be applied (through the standard br dal) to all four disc brakes or only to the front brakes or rear brakes. The valves for changing the brake configuration are located on the floor at the left side of the driver's seat (Fig. 4). To actuate a set of brakes, the appropriate pressure valve is opened (counterclockwise rotation) and its corresponding bleed valve is closed. Caution should be exercised to ensure that the vehicle is not totally without brakes (both pressure valves closed). A schematic of the brake system is provided in Figure 5.

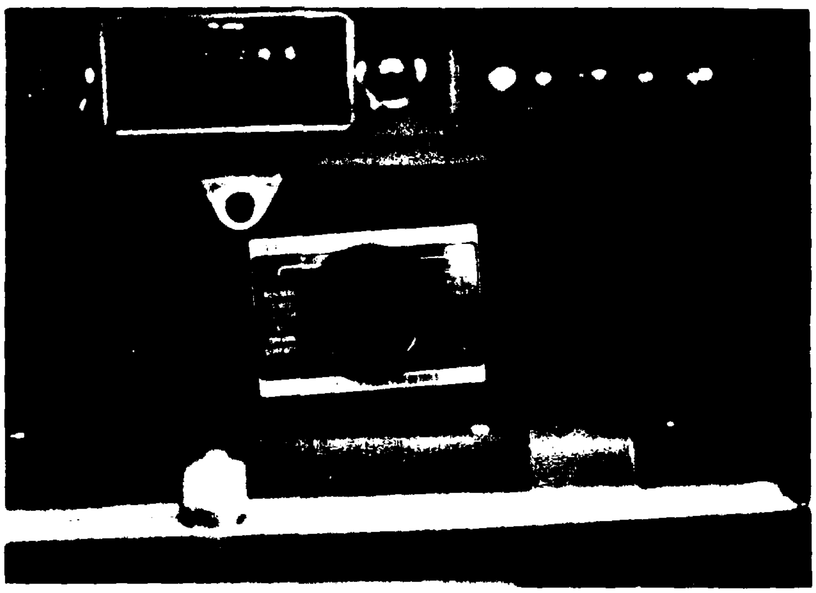


Figure 3. Emergency drive lock control.

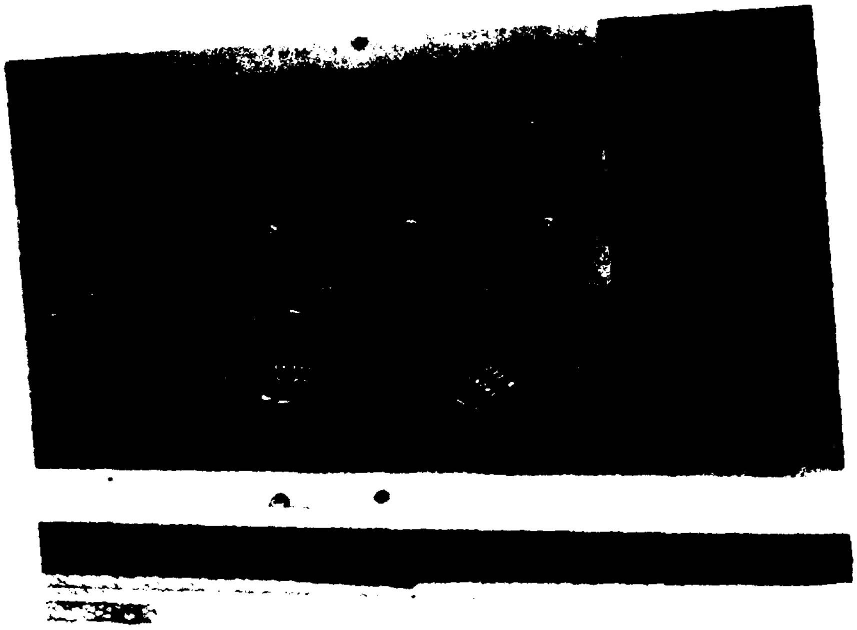


Figure 4. Dual brake system control valves.

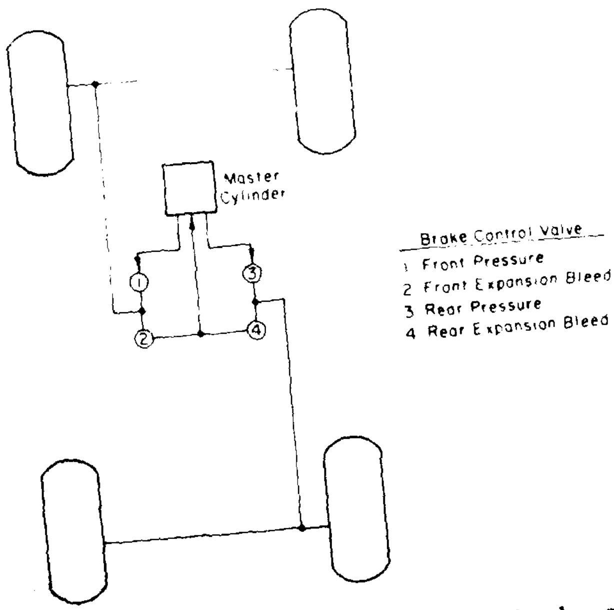


Figure 5. Schematic of modified brake system.

Four air-adjustable shock absorbers take the place of the standard shocks. These are connected in pairs (front two and rear two) to a vacuum-actuated air compressor, which is controlled by two regulator panels (Fig. 6). This system allows the vertical force on the front or rear

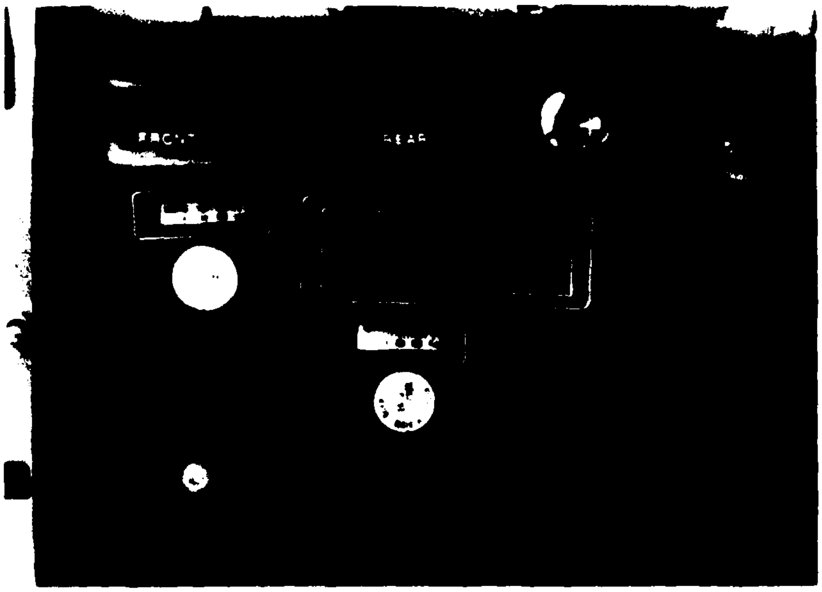


Figure 6. Air-shock-absorber regulator panels.

wheels to be varied by up to 20 lbs through inflation of one set of shocks and deflation of the other set. In addition, greater wheel-well clearance for certain oversize tires can be obtained by inflating the shock absorbers. Vehicle trim is also controlled by appropriate inflation and deflation of the shocks. This is important for aligning the load-cell axes properly for the tire size being tested.

Electrical power (500 W) is supplied for most of the instrumentation from a 12-V d.c. to 115-V a.c. sine-wave static inverter (Topaz type GZ, Fig. 7). The inverter is mounted in the cargo area of the CIV next to a 12-V battery that provides its input. The battery is charged by an auxiliary oversize alternator in the vehicle, and the battery's charge is monitored with a meter located in the instrumentation section of the vehicle. Output from the inverter is sent to an outlet block located in the instrumentation section of the vehicle (Fig. 8).

The vehicle is also equipped with swivel seats for both the driver and passenger to allow them to operate the vehicle and the instrumentation. An overhead 110-V a.c. light has been installed for use during overcast or night conditions. Shock-mounted tables are provided for all of the instrumentation.

Figure 7. Twelve-V d.c. to 115-V a.c. static inverter and battery.

Figure 8. Power strip in the instrumentation section of the vehicle.

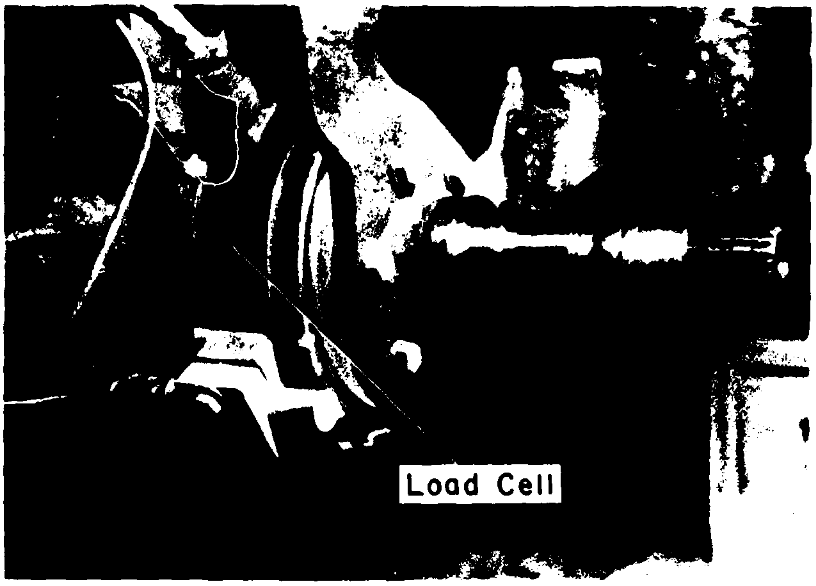


Figure 9. Moment-compensated triaxial load cell.

Electronic measuring equipment

Instrumentation has been added to the vehicle to obtain measurements of pertinent parameters during operation. Descriptions of this equipment and their locations are detailed in this section. Wiring diagrams for this instrumentation are contained in Appendix B.

Central to the CIV are the moment-compensated, triaxial load cells mounted in the two front-wheel assemblies.[1] The load cells are mounted so that they become a vertical section of the cantilevered rod that supports the wheel (Fig. 9). Since the load cells add 10 inches (5 inches each) to the overall wheelbase width, each of the front two axles from the steering universal out were replaced with longer ones. Each load cell is annular to allow the axle to pass through it.

The load cells each contain three, complete, strain-gage Wheatstone bridges that measure forces acting in three, mutually perpendicular directions. These directions are oriented as shown in Figure 10 and will be referred to as vertical, longitudinal and side directions. Moment

[1] Shoberg, R.S. and Wallace, B. (1975) A triaxial automotive wheel force and moment transducer. Society of Automotive Engineers, Paper No. 750049, 25 p.

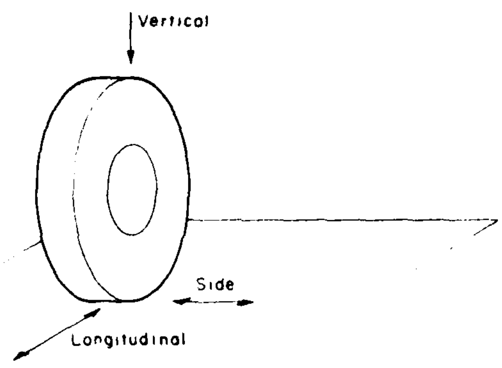


Figure 10. Axes convention used with the triaxial load cells.

compensation is performed by the strain-gage bridges so that the forces read by the bridges represent the forces acting at the tire contact patch. The compensation is such that a torque or a couple applied to the tire registers no force on the load cell.

Each front brake disc is equipped with 100 equally spaced steel nodes on an 8-inch-diameter circle. A counting proximity detector (Red Lion

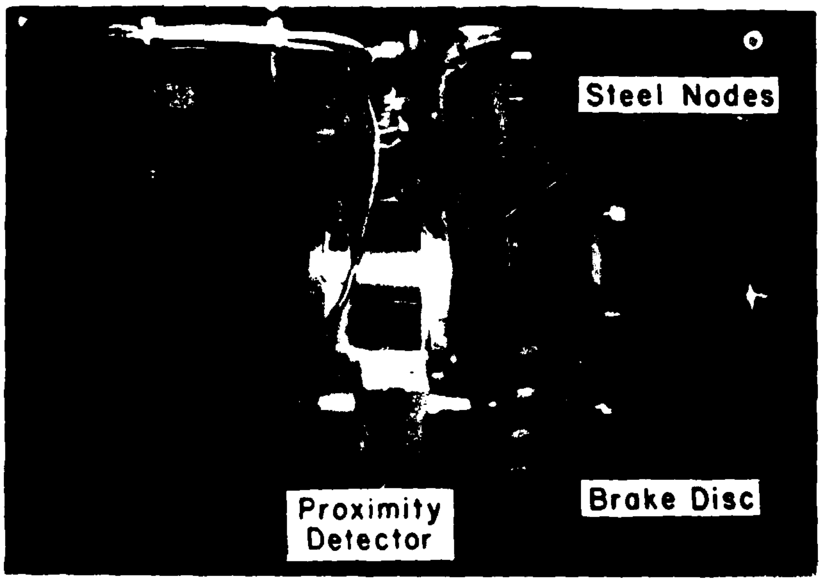


Figure 11. Pulse pickup proximity detector and steel nodes on the brake disc.

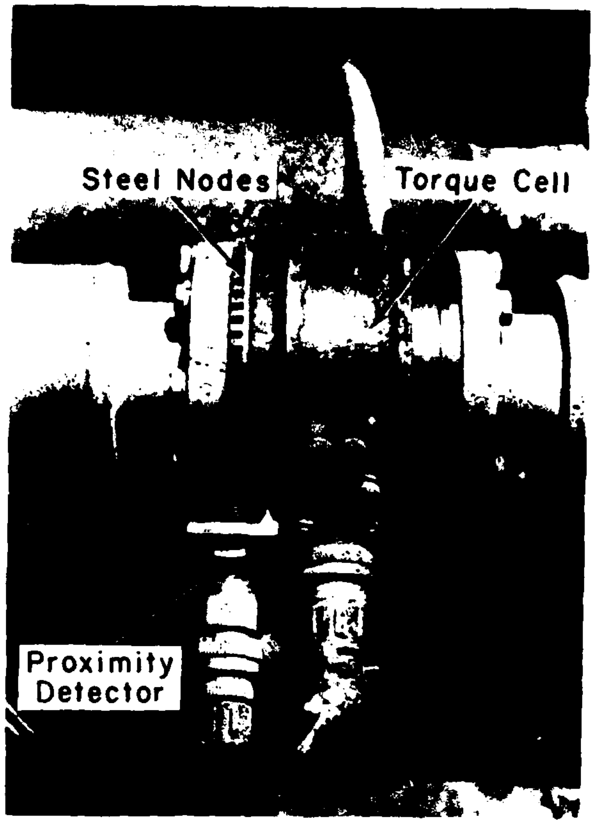
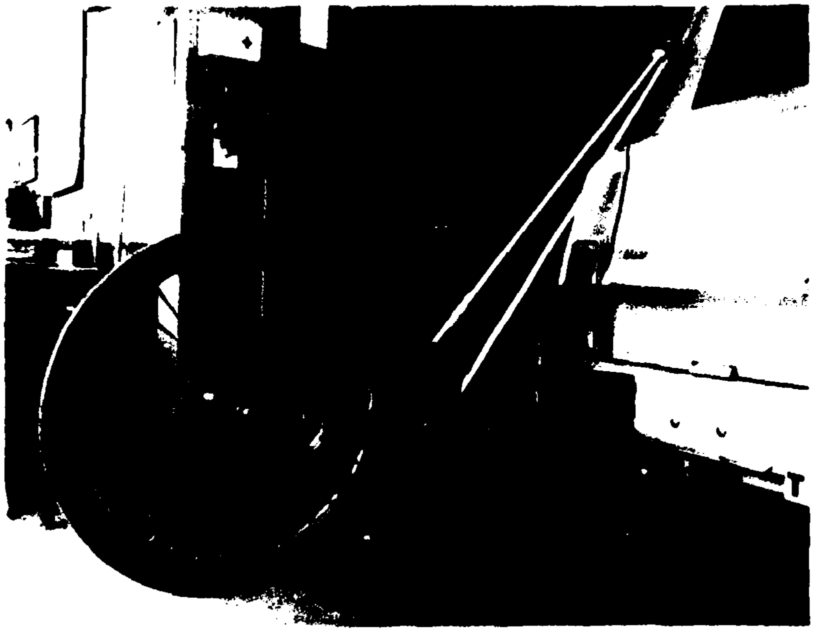


Figure 12. Rear propellor-shaft-mounted torque cell and pulse pickup proximity detector.

Controls Prox-Stik Model PSA-EF) is mounted within 0.05 inches of the ends of the nodes (Fig. 11). This signal yields exact individual wheel distance and velocity values. A similar arrangement (using an Airpax 300 Series control tachometer) on the rear propeller shaft measures the average rear-wheel speed (Fig. 12).

A strain-gage torque sensor (Lebow model 1228) is also mounted on the rear propeller shaft (Fig. 12). Its signal can be used to measure the energy input to the rear wheels during both driving and braking.

To the rear bumper is attached a fifth-wheel assembly for measuring vehicle speed and distance traveled (Fig. 13). The unit consists of a 26-inch by 2.125-inch pneumatic tire mounted on a heavy-duty rim and secured in a mounting frame. Attached to the wheel axle is a tachometer generator (for recording speed) and a transmitter with an etched metal



a. Electric winch pickup.

b. Control switch.

Figure 13. Fifth-wheel assembly.

Figure 14. Fifth-wheel tire with a chain installed for operating on materials with low coefficients of friction.

optical encoder for a 50-pulse-per-foot output (for measuring distance). A tire pressure of 34 psi is required for an accurate distance measurement, and a tire change is required when the tire has worn to within 1/32 inch of the bottom of the tread grooves. The fifth-wheel assembly must not be left in its operating position (down) when the vehicle is backed up; the wheel assembly will jackknife and become damaged.

For operating on ice and other materials with low coefficients of friction, a chain has been installed on the tire to eliminate slippage (Fig. 14). This increases the wheel circumference, and the system must be recalibrated to yield accurate speed and distance measurements.

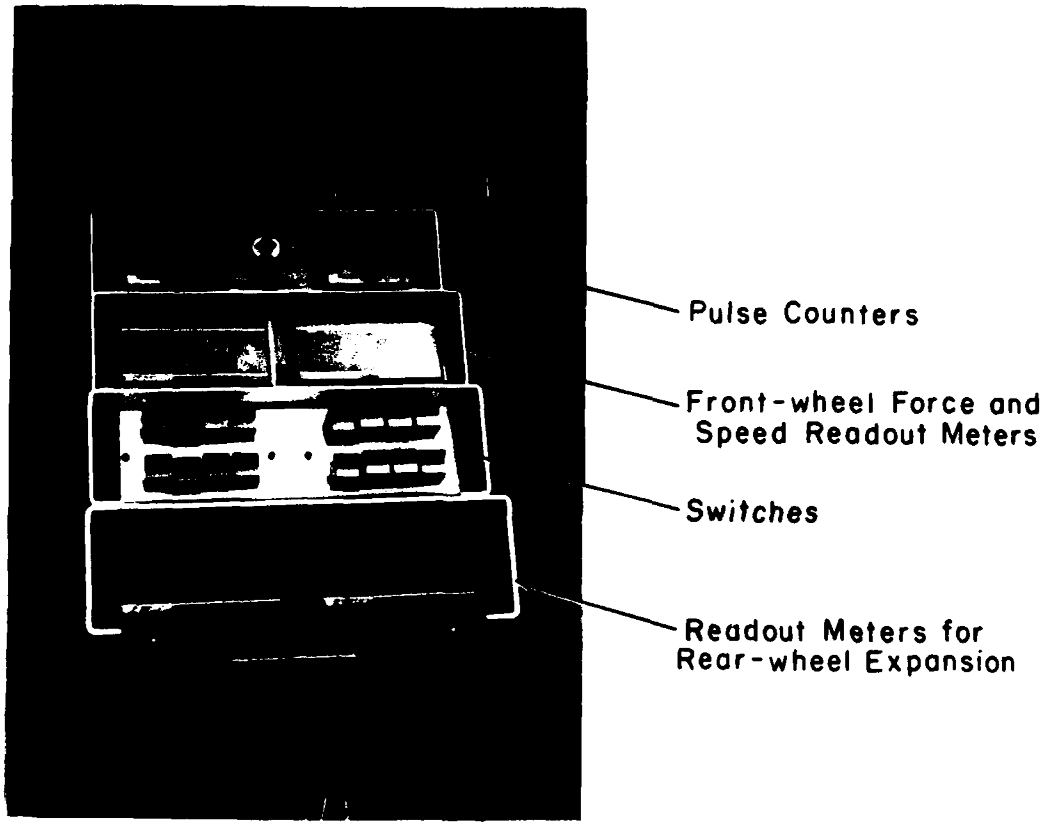
Driver readout

To allow immediate feedback of force and velocity values and to allow the use of a particular measured quantity as a control parameter, a driver readout display unit has been installed (Fig. 15). The main unit consists of three pulse counters (for the front two wheels and the fifth wheel), a right- and left-side digital panel meter (DPM), and two sets of switches (right and left side). Each switch set contains four push-button, double-pole, double-throw switches, which select wheel speed or vertical, longitudinal, or side force. A second set of switches and DPMs are present to accomodate future instrumentation of the rear wheels. The driver readout unit is mounted on the floor between the driver and passenger seats and can be easily read by the vehicle operator. Fifth-wheel speed is read on a digital meter, which is mounted on the top of the dash directly in front of the driver (Fig. 15b, Fig. B8). This allows the operator to maintain a particular vehicle speed without diverting his eyesight from the test course.

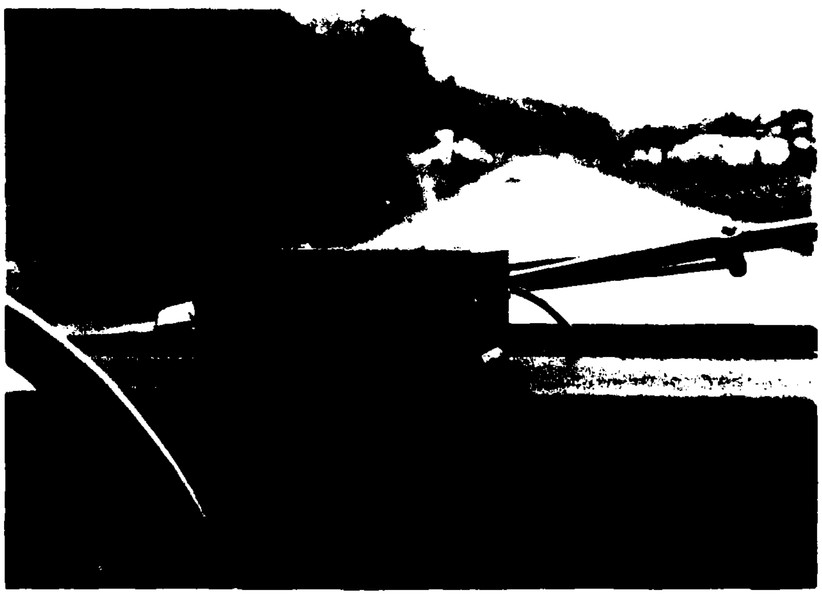
The pulse counters require a 12 V d.c. signal while the DPMs need 110 V a.c. Both are supplied from the velocity signal conditioner unit (described later) and can be switched with the master switch on the front of the conditioner. The fifth-wheel unit operates on 12 V d.c., which is supplied by a hard-wire connection to the vehicle's main battery. A switch on the readout display unit activates the whole fifth-wheel assembly. A switch on the pulse counter box (Fig. B9) is used to interrupt the input pulse train to allow pulse count recording for a discrete interval. The total distance can be calculated from the pulse count; the fifth-wheel outputs 50 pulses per foot of travel (the pulse counter reads every other pulse on the fifth-wheel). Thus the total count divided by 25 yields the distance traveled in feet. The front wheels output 100 pulses per revolution, so the rolling circumference of the tires is necessary to convert the number of front wheel pulses to distance.

The DPMs receive their input signal (Fig. B10) by way of the selector switches (Fig. B11). When displaying load-cell readings the DPMs read in hundredths of millivolts and represent the actual force in pounds. A decimal point is added to the DPM display when a velocity channel is displayed; the readout is in miles per hour.

To facilitate driver readout in actual pounds of force and speed, the input signal, piggybacked from the input leads to the Series 400



a. Equipment mounted on the floor.



b. Fifth-wheel speed readout mounted on the dash.

Figure 15. Driver readout unit.

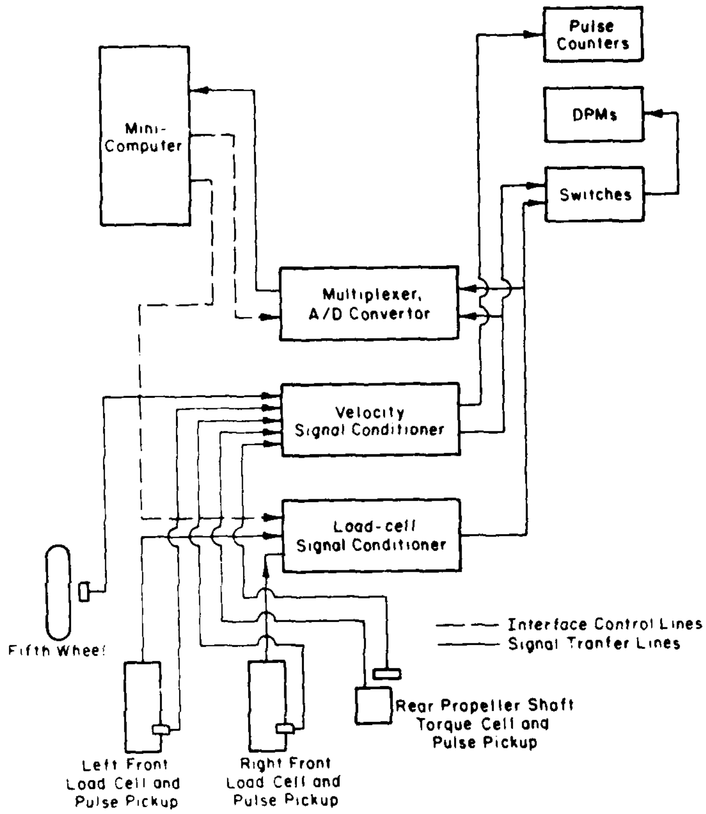


Figure 16. Block diagram of the instrumentation installed in the CIV.

multiplexer (described later), must be zero-adjusted and scaled. This is accomplished by a differential amplifier, which, for space and convenience considerations, was constructed on a blank Series 400 card and is housed in the multiplexer box. A schematic and connector instructions are suppled in Figures B12 and B13.

DATA ACQUISITION AND MANIPULATION EQUIPMENT

Up to this point the description of the CIV has involved basically nonremovable or integral parts of the vehicle (the external fifth-wheel assembly is removable). If the proper inputs to and outputs from the measuring devices are satisfied, any system for readout and recording could be attached. This section contains a description of the present data acquisition equipment and its operation. Figure 16 is a general block diagram of this equipment.

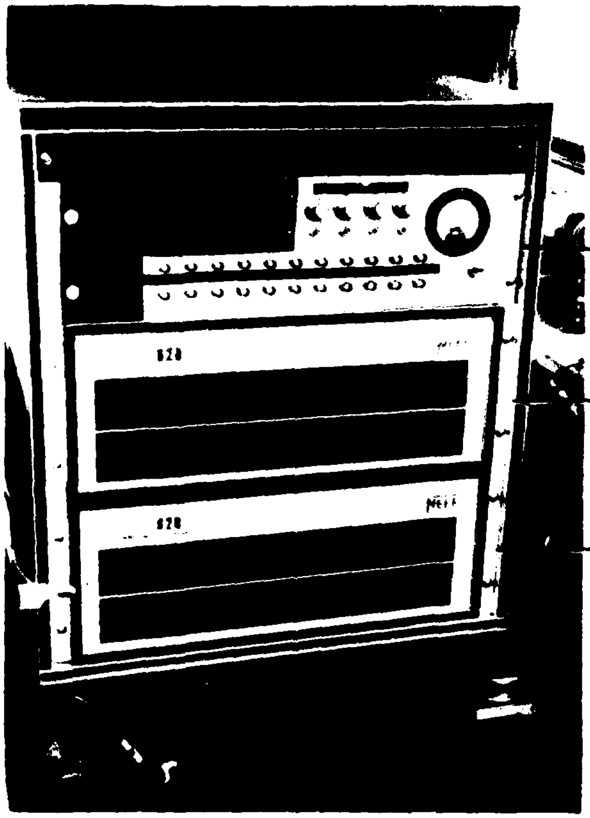


Figure 17. Data acquisition equipment.

Eleven channels of information have been identified; seven are force measurements from load cells (strain-gage bridges) and four are velocity measurements from a tachometer generator or pulse pickups. Each load-cell and pulse-pickup channel requires an excitation or power source in order to function. This power is supplied by two signal conditioners, one for the load cells and the other to configure the velocity channels.

Load-cell signal conditioner

The load-cell signal conditioner is a Neff Series 300 model (Fig. 17) and allows each channel to be separately configured for a particular transducer type. The signal conditioner provides a constant-voltage (2-10 V d.c.) or a constant current (2-50 mA) excitation. It also furnishes circuitry for bridge completion and remote-control calibration.

Connections to the Series 300 from the load cells are hard-wired in groups of four channels to a screw terminal p-c card edge connector

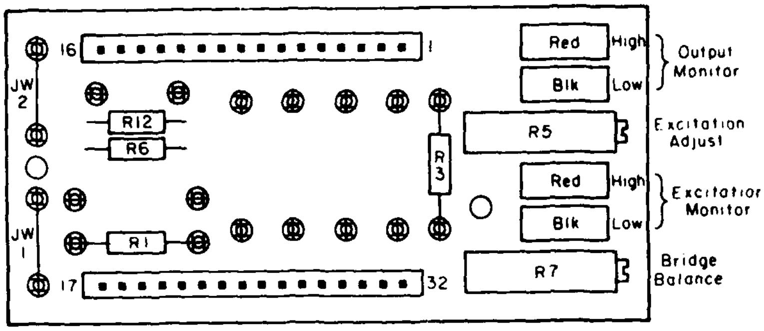


Figure 18. Series 300 strain-gage mode card.

accessible from the rear of the unit. A typical connector and the key to attachment is illustrated in Figure B5.

The Series 300 is equipped with four-channel input conditioning plug-in circuit cards. Each of these cards contains an excitation power supply, relays and calibration circuits for each of the four channels it conditions. Four mode cards may be attached to each input conditioning card. The mode cards provide circuitry for bridge completion and balance, and positions for mounting shunt resistors. Figure 18 shows the strain-gage mode card as it is configured for each of the load-cell channels. Excitation is monitored from the front of the card and adjusted with resistor R5. Likewise, transducer output can be monitored on the mode card and the bridge balanced with R7. The system is normally adjusted to provide a 10-V d.c. excitation to each of the seven load-cell channels.

Output from the Series 300 comes from the rear-mounted card-edge connectors and consists of high and low signal terminals and cable shield connections (Fig. B5).

The Series 300 can be operated in either a local or remote mode as chosen by switch SW5 on the reference supply, relay driver card (Fig. 19). In the local mode an LED indicator and switches SW1 - SW4 are activated. Relay K101 is activated by placing switch SW1 in position 1 (not position 0 as indicated in the Neff Series 300 manual). This enables voltage calibration of each channel when the optional voltage dividers are installed. The present system does not have these dividers. When K101 is activated, a short is placed across the output leads, allowing a system zero-point reference.

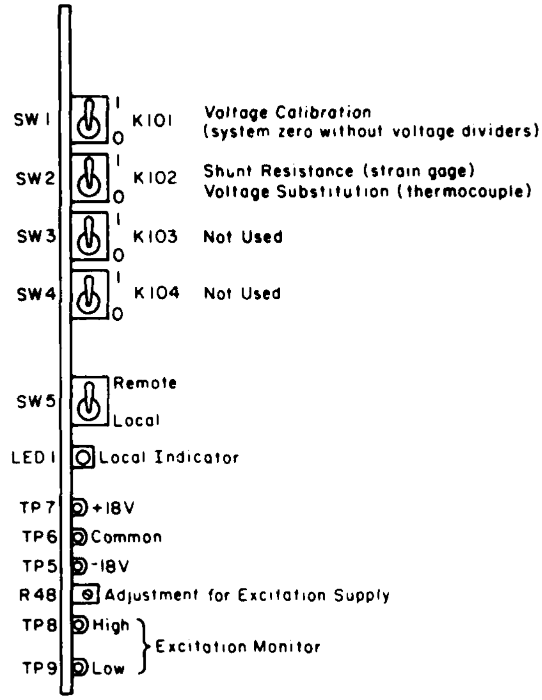


Figure 19. Series 300 reference supply, relay driver card (0 = off, 1 = on).

Table 1. Shunt-resistor load equivalent values.

Channel	Signal	Resistor Value (KΩ)	Load Equivalent (lbs)
1	R. Vertical	150	2124
2	R. Longitudinal	150	2001
3	R. Side	300	1992
5	L. Vertical	150	2184
6	L. Longitudinal	150	2011
7	L. Side	300	2108
9	Torque Cell	60	594 (in-lbs)

The activation of relay K102 puts resistor R1 (Fig. 18) into the bridge parallel with one arm of the bridge. This enables single-point shunt calibration, provided the load equivalent of the resistor has been calculated and the bridge has been balanced (zero output) before K102 is activated. It is important to zero the bridge first to avoid the possibility of nonlinear calibration. Shunt values for each load-cell channel on the CIV are listed in Table 1. Relays K103 and K104 are not used with the standard input conditioning cards in the CIV.

Switches SW1 - SW4 can also be operated remotely if SW5 is in the remote position. This is accomplished with instructions entered through an interface (discussed later) connected to port J15 (CAL ADDR in) located on the back of the Series 300.

Velocity signal conditioner

A second signal conditioner (Fig. 17) provides the necessary circuitry for the velocity channels. This unit was initially constructed by NATC and has subsequently been modified by CRREL to function properly with the new instrumentation. The velocity signal conditioner converts the incoming pulse frequencies (from the proximity detectors) to a d.c. voltage, which represents speed. Three of these converters are present, one for each front wheel and one for the rear propeller shaft. Conversion from frequency to d.c. for the fifth wheel is not necessary since an analog signal is output from the assembly's tachometer generator. Circuitry is provided for making scaling adjustments (located on the front face) and for filtering (switches on the back panel). Input and output from the velocity signal conditioner is via connectors located on the back of the unit (Fig. B6).

Multiplexer and analog-digital converter

Conditioned analog (d.c. voltage) signals from each of the 11 data channels are output from the two signal conditioners into a Neff Series 400 multiplexer (Fig. 17). The Series 400 contains a high-speed analog-signal multiplexer, programmable gain amplifiers, a sample-and-hold amplifier, an analog-to-digital converter and logic for interface control. The unit houses differential multiplexer plug-in circuit cards containing 10-Hz low-pass filters and remote-controlled channel switches for 16 channels. The output from the multiplexer card is applied to a two-stage programmable gain amplifier, which allows full-scale input sensitivities from 5 mV to 10.24 V. The signal is then passed through a sampling-rate filter and a sample-and-hold amplifier before analog-to-digital conversion and output.

Input to the Series 400 from the Series 300 and velocity signal conditioners is hard-wired in groups of 16 channels to a screw terminal p-c card edge connector located in the rear of the unit. Attachment instructions are illustrated in Fig. B7.

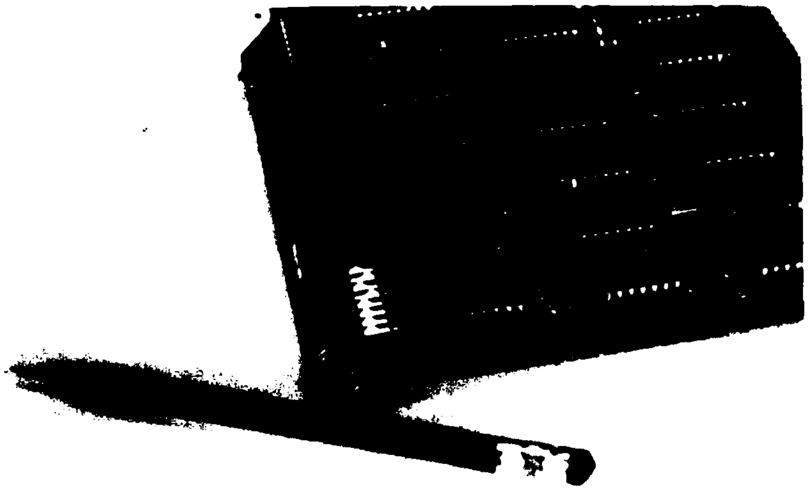


Figure 20. Series 400 last-channel switches.

Unlike the Series 300, the Series 400 can only be operated in remote mode. An optional control panel (not present in the CIV) would allow some local control.

The Series 400 can be operated in one of two channel addressing modes, sequential or random. During sequential operation, data sampling begins at channel 0 and continues until the last channel is sampled. The channel address pointer is automatically advanced by one each time a channel is sampled until the last channel is converted, at which point the address pointer is reset to channel 0. The number of the last channel to be sampled is set on the last-channel switches (Fig. 20) located on the logic control card in slot 2 of the card cage. The switches consist of a miniature eight-toggle assembly. Each switch, when set to the open position, generates a logic one while the closed position produces a logic zero. The last channel to be sampled is then chosen by producing a base two number (ones and zeros), which represents the last-channel address. For convenience, base ten numbers are listed beside each toggle. The last-channel address can be easily set by adding the appropriate combination of base ten numbers and putting each of their toggles to the open position, with all others closed. Channel addresses begin with 0, so that for a system with

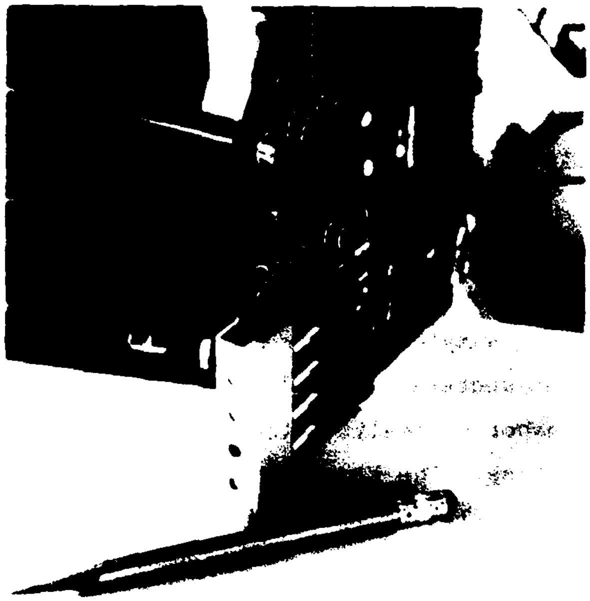


Figure 21. Series 400 throughput-rate switches.

52 input signals the last channel address is 51. (Last-channel switches for this example would have toggles set open for the base ten numbers 1, 2, 16 and 32, while all the remaining toggles would be in the closed position.)

Random mode addressing requires that the system be fed a channel address each time a request-for-conversion is initiated. When set to random mode the Series 400 deactivates the last-channel switches.

The actual time required to sample a channel is governed by the throughput-rate switches (Fig. 21), which are mounted on the filter, sample-and-hold card in slot 4 of the card cage. These push-button switches represent (from top to bottom) 1.25-, 2.5-, 5.0- and 10-kHz conversion rates. Selection of a throughput rate not only sets the per channel sampling time but automatically adjusts a sampling-rate filter to an appropriate bandwidth for that conversion rate.

The Series 400, as mentioned previously, is operated remotely through an interface. Details of operation via the interface are covered in a separate section; however, the operation of the Series 400 is briefly covered here to avoid confusion with interfacing instructions and functioning.

Before actual sampling, the correct throughput-rate and last-channel switches must be set. To select the proper conversion rate, the total number of channels to be sampled must be multiplied by the desired scan rate (time between successive samples on one channel). This number indicates the total number of readings (conversion cycles) that must be performed per unit of time. The throughput-rate switch must be set so that conversions are accomplished at this speed or faster. The last-channel switches should indicate a number that is one less than the total number of channels to be scanned.

Operating the multiplexer in a sequential addressing mode requires that the SEQ/RAN line be set to a positive-true level (binary 1). This instruction resets the address pointer to channel 0 and activates the last-channel switches. A gain code is then read, which represents the magnitude of the expected full-scale analog input. Gain codes and their corresponding maximum sensitivity levels are shown in Table 2. Sampling may now begin by issuing a positive-true level on the STEP/STROBE line. When the STEP/STROBE line is set, the Series 400 begins the conversion cycle and may not be interrupted again until the system has output a data word and has issued an EOC (end of conversion) pulse. On the trailing edge of the EOC pulse, the channel address pointer is advanced by one, and the system can again accept a STEP/STROBE input. Data may be read on the trailing edge of the EOC pulse, even if a new conversion cycle has been initiated.

Random mode sampling is accomplished by not setting the SEQ/RAN line (binary 0). The gain code and channel address must be specified for each conversion request and may be issued before or with each STEP/STROBE pulse. As with sequential operation, an EOC pulse follows output of a data word and a new conversion cycle may be initiated.

The minimum time required to complete a scan (one sample taken for each channel in the system) is found by multiplying the number of channels by the selected throughput sampling time. This assumes that STEP/STROBE pulses are issued immediately after an EOC pulse is received. Sampling

Table 2. Gain code - full scale sensitivity values

Gain code			
Base 10	Binary	Gain	Sensitivity
11	1011	2048	5 mV
10	1010	1024	10 mV
9	1001	512	20 mV
8	1000	256	40 mV
7	0111	128	80 mV
6	0110	64	160 mV
5	0101	32	320 mV
4	0100	16	640 mV
3	0011	8	1.28 V
2	0010	4	2.56 V
1	0001	2	5.12 V
0	0000	1	10.24 V

rates (channel-to-channel delay) can then be governed by the time between consecutive STEP/STROBE pulses. The scan rate is a function of the time used to sample all the channels plus any delay inserted between the EOC pulse received from the last channel and the STEP/STROBE pulse for the first channel.

Output from the Series 400 consists of a digitized two's-complement 12-bit word. The output word is available to the interface on the output register during the channel period following analog-to-digital conversion. The output interface is connected through port J6 on the rear of the Series 400. Input instructions during remote operation of the multiplexer are transfered via the interface through port J8.

Minicomputer

The Series 300 and 400 are operated in the remote mode by a Hewlett-Packard 9845B minicomputer (Fig. 22). The computer, through a 16-bit parallel interface, sends instructions that set appropriate switches, furnish sequential or random sampling, gain and channel address information, and initiate conversion cycles. Data words sent back by the Series 400 are read and stored for later manipulation.

The 9845 has two 217K-byte tape cartridge drives, which are used for mass storage of data and programs. A 187K-byte read-write memory is available for working semiconductor memory. Data and programs can be displayed with the computer's 20-line, 80-column CRT or the 80-column internal

Figure 22. Hewlett-Packard 9845 minicomputer.

thermal printer. A graphics read-only-memory (ROM) allows data plots to be generated and outputs in video or hard copy form. The 9845 also has a real-time clock, which is used to measure time intervals accurately and to generate interrupts for initiating a scan or conversion cycle. The entire data acquisition system is operated through the software instructions used by the computer.

SOFTWARE

The HP9845 computer programs for use with the CIV are written in BASIC programming language. Two primary programs are present, one which controls and acquires data during operation of the vehicle (DATACQ) and one for reading and manipulating stored data (READ-2). These programs are listed in Appendix C.

The programs are written in an interactive mode and prompt the user for the required input. Where convenient, a menu is provided to allow the user to choose the desired routine.

The data acquisition program (DATACQ) is divided into a main program, which gathers documentary information about the locality and conditions present in the test area, and several subprograms. The main program begins by checking to see that the data storage cartridge (tape drive T14 on the 9845) is not full (42 files). If full the program directs the user through a cartridge-changing procedure.

The user must next choose whether to proceed into the main program or to run the calibration subprogram (Calibration) (line 360). The purpose of the calibration subprogram is to take zero-load, zero-speed readings and shunt-resistance, fixed-speed readings and to calculate the appropriate scale factors for each channel. The subprogram stores the zeros and scale factors in a file which always begins with the letter C. A new calibration file should be created each time the data acquisition system is turned on, the front tires are changed, or the air pressure in the shock absorbers is changed.

Following input and printout of the documentary data (lines 400-1250), a channel sampling subprogram (Scan) is called (line 1260), which performs the actual data conversion and transfer. Subprogram Scan is set up with a series of two interrupts. The 9845 real-time clock is used to generate interrupts at a user-chosen rate. This rate represents the frequency with which a call is made to the subroutine Sample, which sequentially collects a data word from each channel in the system. The clock interrupts a meaningless infinite loop (lines 1890 and 1900), which allows the Sample routine to be addressed as quickly as possible following the clock signal.

Data acquisition may be terminated in two ways. The program is set up to hold a maximum of 1400 data points per channel. The clock interrupts and the Sample routine are automatically disabled when 1400 data scans have been completed. Should the test be finished before the maximum number of scans is completed, data acquisition can be terminated by the user by pressing the special function key K0, which is defined in an ON KEY statement (line 1730). This user-generated interrupt has a higher priority than the clock-generated interrupt, so it is always serviced when called. Details of the coding used in the Scan subprogram to control the data acquisition equipment will be covered in the interfacing section.

When data acquisition is complete, a menu is offered the user (lines 1310-1420). Included are subprograms for storing data, viewing the raw data, plotting the data, stopping the program, rerunning the program, calibrating the system, and generating several calculated values. The Store subprogram saves the documentary data gathered in the main program and all of the data acquired by Scan. The data taken in Scan are stored in their internal, unformated binary form. This greatly conserves storage space on the tape cartridge. Any subprogram that requires viewing or calculation of meaningful numbers requires conversion of the data acquired in Scan. The Convert subprogram is automatically accessed when a subprogram requiring meaningful values is chosen from the menu. Using a variable-to-variable transfer and the appropriate calibration file, the binary data are converted to numbers in units of pounds and miles per hour. As part of the Convert routine, the binary data must be inverted (zeros changed to ones and ones changed to zeros). This is accomplished with the BINCMP function (line 3950) and is necessary because the Series 400 uses positive-true logic, while the 9845 interface and computer use negative-true logic.

Data plots can be created with the Plots subprogram. Any of the measured quantities may be chosen for the ordinate, while time, distance or differential interface velocity are the choices for the abscissa. Both the right- and left-wheel data (for the chosen quantity) are plotted on a single graph. Distance, although not measured directly, is found by integration of the speed vs time data. Since both wheel and vehicle (fifth-wheel) speeds are being measured, plots can be with wheel or vehicle distance.

Several value-generating subprograms are included in DATACO. The Average subprogram gives the user the choice of which data channels he wants average force or speed values for. The value returned can be the average for any percent (chosen by the user) of the data points taken. Subprogram Average sorts the data into an ascending order array and then averages the upper percent chosen by the user. If a 100% average is requested, the array-sorting routine is omitted and all the data points are averaged.

Subprogram Slip-energy is an integration routine that calculates the area under the longitudinal force vs distance curve. The energy term generated by the subprogram can be relative to wheel or vehicle distance.

Program READ-2 is designed to access data files which were acquired and stored by DATACO. This program is also structured with a main program and several subprograms. The main program requests the file name of the data file to be viewed (line 140) and reads the documentary and test data from the file. The documentary data may or may not be viewed. Test data are then converted with subroutine Convert, just as in DATACO. Access to the subprograms is through a menu item selection (lines 420-520). The READ-2 menu contains the same routines as DATACO, except Store and Calibration.

Programs DATACO and READ-2 are stored on the tape cartridge labeled "master cartridge." This cartridge must be run from tape drive T15 on the 9845 computer. Data cartridges, either for writing data to or reading data from, are operated in tape drive T14. The master cartridge contains a program AUTOST, which is designed to load and run DATACO or READ-2, depending on the user's choice. If the AUTOST key on the computer is latched in the down position before the power is turned on to the computer, program AUTOST is automatically loaded and run. Thus, by depressing the AUTOST key before turning the power on, the user need only to respond to self-directed questions posed by the computer; no previous knowledge of the 9845 computer or its operation is necessary for running programs DATACO or READ-2.

INTERFACING

Interfacing, the process of intercommunication between the 9845 computer and the programmable peripherals, is performed in subprograms Scan and Calibration. The interface card used to implement communication with the Neff instrumentation is a 16-bit-parallel interface and cable (Fig.

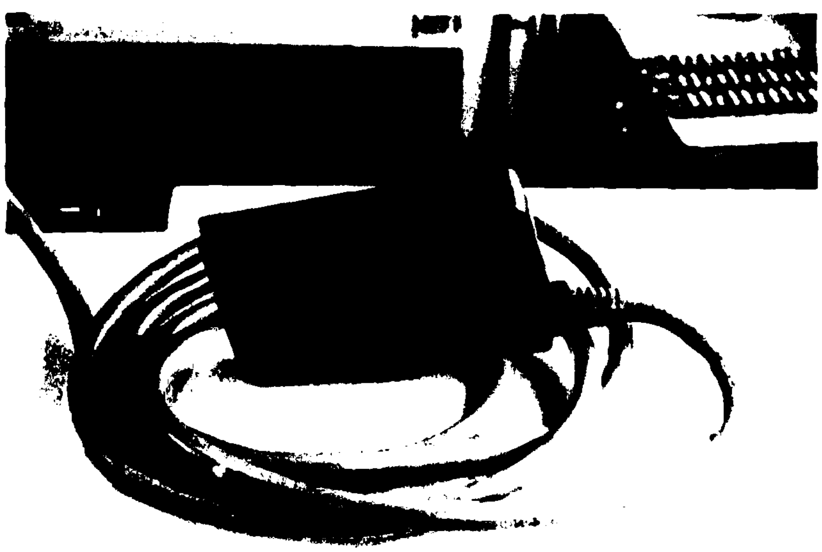


Figure 23. Sixteen-bit-parallel interface and cable.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
INT	DMA	RESET	AH	–	–	CTL1	CTL0

INT: Interrupt Enable on FLG = Ready
DMA: Direct Memory Access Enable
RESET: Reset the Card to Its Power-on State
AH: Auto Handshake Enable
X: These bits are not used and may be a 1 or a 0
CTL1,0: General User-definable Control Bits

Figure 24. Bit assignments for the R5-out interface register.

23). This interface allows 16 bits of binary data to be transferred simultaneously either for input or output. Several other peripheral control and status lines are also present.

All communication with the 98032A interface is addressed to the R5 interface register. The specific bit arrangement which is sent to the register dictates the interface's mode of operation. Figure 24 illustrates the bit assignments for the R5-out register (information sent by the computer). Input of a binary 1 to any bit constitutes "setting" a particular bit.

Bit 7, when set, instructs the interface to request an interrupt of the input-output (I/O) processor whenever the peripheral indicates (to the interface) it is ready. Bit 6 enables a direct memory access (DMA) transfer each time the peripheral indicates it is ready. A normal DMA transfer is handled automatically by the I/O read-only-memory (ROM), and thus program set and clear of bit 6 is unnecessary. Bit 5, the reset bit, is used to return the interface to its power-on state (bits 4, 6 and 7 cleared). Bit 4 of the R5 out register is used to operate in an "auto-handshake" mode, and like bit 6, it is normally operated automatically with the I/O ROM. No meaning is placed on bits 3 and 2; their values are ignored. Register bit 0 is used with the CIV system to direct instructions to the two programmable peripherals (Series 300 and 400). When the bit is set, subsequent I/O instructions are directed to the multiplexer (Series 400). A binary zero in bit 0 causes remote instructions to be sent to the Series 300 signal conditioner. Bit 1 is not used with the CIV system.

The control byte (the bit pattern sent to the R5-out register) is set up in the CONTROL MASK programming statement. This statement defines the bit configuration for ENTER and OUTPUT transfers. The mask value is the

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
INT	DMA	1	0	IID	IOD	STI1	STI0

INT: Interrupt Enabled Indicator
DMA: DMA Enabled Indicator
IID: Invert Input Data Jumper Installed
IOD: Invert Output Data Jumper Installed
STI1,0: General User-definable Status Bits

Figure 25. Bit assignments for the R5-in interface register.

base 10 equivalent of the binary sequence of ones and zeros that set or clear the R5 register bits. The CARD ENABLE statement is then used to actually write the current mask value to the R5 register.

Operational information (nondata) is sent back to the computer (through the interface) through the R5-in register. This eight-bit register is interrogated by the computer to gain information about the status of the interface. The bit assignments for the R5-in register are shown in Figure 25.

Bits 6 and 7 indicate (when their value is binary one) whether or not the interface card has been made available for DMA or interrupts, respectively. Bits 4 and 5 are set at the factory. Bits 2 and 3 indicate the presence or absence of hardwire jumpers on the interface card. The two jumpers tested for by bits 2 and 3 have been installed on the 98032A interface card and indicate that the incoming and outgoing binary data need to be inverted (complemented). This allows meaningful communication between the negative-true-logic computer and the positive-true-logic Neff peripherals.

The final two bits, 1 and 0, are defined by the user and may be connected to any peripheral output lines. Line connections between the interface and peripherals are shown in Figure 26. The standard Hewlett Packard nomenclature is shown beside each interface connection. The signals carried by these lines to and from the Series 300 and 400 and their meanings to the peripherals are also shown in Figure 26. Several standard jumpers are installed on the interface, allowing the computer-interface-peripheral system to operate efficiently (Table 3).

To fully explain the interfacing technique and how it fits in with the information presented in the sections covering data acquisition equipment

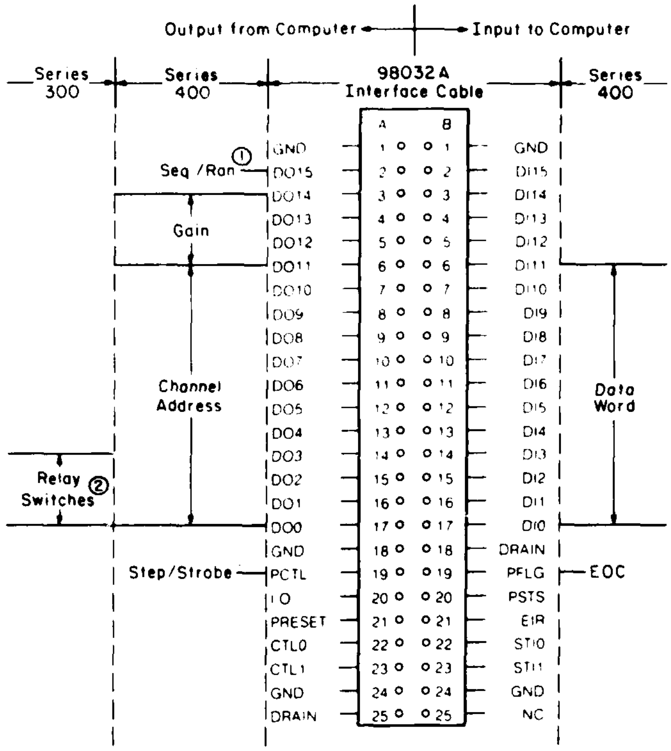


Figure 26. Cable connections between the Series 300 and 400 peripherals and the bit-parallel interface.
1. Random mode: 0; sequential mode: 1.
2. Switches activates: 0; off or normal operation: 1.

and software, portions of the Calibration and Scan subprograms will be described line by line. In the Calibration subprogram (program DATACO), line 2420 issues the first interfacing-related instruction. As previously mentioned, the CONTROL MASK statement sets the bit pattern for the R5-out register. The bit pattern in line 2420 is defined by a base 10 zero (which converts to a binary zero) and is meant only for the interface with its select code set to 6 (thus the 6 before the semicolon). Line 2430 writes this bit pattern to the R5 register of the interface with select code 6. Figure 24 shows that the function of lines 2420 and 2430 is to clear all seven of the control byte bits. Bit 0 being cleared, subsequent instructions will be directed to the Series 300. Line 2440 writes a data word to the Series 300 through the interface on select code 6 using the work handshake (WHS) mode of data transfer. Handshake is a term that describes the sequence of operations which occur when a data unit is transferred. The

Table 3. Jumper wires installed on the 98032A interface.

Jumper	
9	Clocks the high input byte when PFLG goes ready from busy.
D	Clocks the low input byte when PFLG goes ready from busy.
1	Sets bit 3 in the status register, changes the input data lines to positive true logic.
2	Sets bit 2 in the status register, changes the output data lines to positive true logic.
3	Complements the logic sense of PCTL; high = control set and low = control clear.
B	Selects the words input mode.
F	Selects the words output mode.
7	Allows the calculator to activate the DMA (Direct Memory Access) mode of operation.

handshake's basic purpose is to ensure proper timing during the transfer process. The data word sent by line 2440 is the binary equivalent of (base 10) 15, which is 1111. Figure 26 shows that this bit pattern clears (i.e. normal operation) all of the relay switches in the Series 300. Thus the peripheral unit is readied for normal data gathering. The format used to send this bit pattern is indictated by the USING "#, W" portion of the statement. The # specifier suppresses both the carriage-return and the line-feed normally output at the end of an output list. The W specifies that two bytes of two's complement binary data is to be output.

Lines 2450 and 2460 set the R5-out register bit pattern so that all bits are cleared except bit 0. This pattern directs future instructions to the Series 400. The OUTPUT statement in line 2490 is again directed to the 98032A interface (set to select code 6) and uses the same transfer and formatting types. The data word sent to the Series 400 is the binary equivalent of the base 10 result of the expression to the right of the semicolon. The gain code (represented by variable Gain) is defined in line 2350 and sets the system sensitivity as shown in Table 2. Gain is multiplied by 2048 so that the gain code will be placed in bits 11 - 14 of the output (from the computer) word (Fig. 26). Since bit 15 has not been set, the Series 400 is prepared to run in a random channel-sampling mode, and thus requires a channel address for each call to the peripheral. The channel address is given by the (J-1) expression, which is defined by the loop set up in line 2480. Since it is handy to think of the channels as being numbered 1 - 11, the channel address (for the Series 400) must be decreased by one since the peripheral channel addresses begin with zero. (With Gain = 10 and J = 5 the output word equals 20484, which translates to 0101000000000100 in binary. This bit pattern is sent to the Series 400 on the interface cable lines DO0 - DO15.)

The ENTER command (line 2500) reads the data word on cable lines DI0 - DI15. Since the Series 400 employs a 12-bit A/D convertor, only the first 11 lines contain the data word. The same interface select code is referenced by the ENTER statement. The format for input cancels the line-feed terminator (#, data entry terminates with the last item in the enter list), and requests input of one 16-bit word from an interface (W).

Lines 2530 - 2630 repeat this sequence; however, a 13 (binary 1101) is output to the Series 300 (line 2550), which activates switch K102 for shunt-resistance substitution.

The next series of instructions in the subprogram Calibration that involve interfacing are lines 2720 - 3050. The Series 300 is switched back to normal operation in line 2740. The output word sent to the Series 400 (line 2770) includes the gain code (multiplied by 2048 to move it into bits 11 - 14). The -32768 value converts to a binary number, which has a one in bit 15 and zeros in all others. This sets the Series 400 for sequential mode sampling, and thus no channel addresses are necessary. The call to sequential mode sampling in line 2770 also resets the channel address pointer to channel 0. Upon each successive conversion the pointer is advanced by one until the last channel (set by the last-channel switch) is reached.

Lines 2890 - 3050 repeat the sequence in lines 2720-2880, except with the Series 300 operating with switch K102 activated. The data acquisition sequence in lines 3060-3260 is performed in the random sampling mode (line 3230) and with the Series 300 in normal operating mode (line 3080).

The Scan subprogram involves interfacing to both the 98032A interface (select code 6) and the real-time clock interface (select code 9). Lines 1660 - 1680 ensure that the switches in the Series 300 are set for normal operation. Instructions in lines 1690 and 1700 set up the real-time clock for operation as a counter and as an interrupt producer. The ON INT #9 statement (line 1740) instructs the program where to branch when an interrupt request is received from the clock. This interrupt is given a priority of 8 so as to be overridden by any user-produced interrupt produced by key K0 (defined with priority 15 in line 1730).

The mask value of 128 (line 1750), which is defined for the clock, enables the clock to request interrupts (sets bit 7 of the R5 out register). Interrupts from the clock are generated at an interval (scan rate) that is defined in line 1760. The CARD ENABLE 9 statement enables the clock to request an interrupt of the processor for the purpose of transferring program control (since it is being used with an ON INT statement). Lines 1780 - 1800 set up the Series 400 for sequential mode sampling and set the system gain.

The CONTROL MASK statement in line 1810 sets bit 5 (and bit 0) of the 98032A R5-out register. Bit 5 is used to return the interface to its power-on state, which causes the PCTL handshake line to return to high. Normally this would indicate that control is not set; however, with jumper 3 installed, PCTL high indicates that control is set.

The PCTL line is paired with the PFLG line. The peripheral sets control (low-to-high transition) on the PCTL line by a low-to-high transition on the PFLG line. Figure 27 illustrates how these features accomplish the data handshake process. The CONTROL MASK statement (line 1810) then defines a bit arrangement which gives control over the state of the PCTL (STEP/STROBE) line. When the CARD ENABLE 6 statement is executed, the mask bit arrangement is sent to the interface and the STEP/STROBE pulse is issued.

Line 1850 causes a 20-ms delay to be completed by the interrupt unit of the clock before any interrupts are issued. This is to allow the beginning time reading (lines 1870 and 1880) to be completed before any interrupts are requested. Line 1860 actually starts the clock and begins

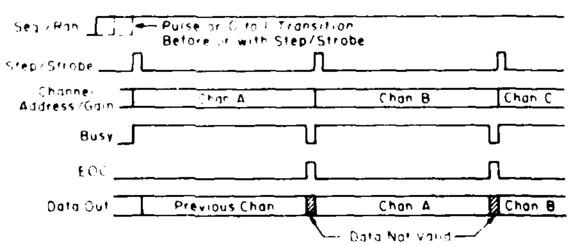


Figure 27. Sample sequence timing.

the data acquisition process. Program flow then continues into an endless loop. The ON INT #9, CONTROL MASK 128, CARD ENABLE 9 sequence produces clock interrupts that branch program flow to the subroutine Sample. When an interrupt request is received, the processor first completes execution of the current line before interrupt branching is taken. Thus, the rapidly executed meaningless statements in lines 1890 and 1900 are inserted in the program.

Upon receiving the request for an interrupt, the processor branches to subroutine Sample. The clock is made available for interrupts (line 1910) so that the scan rate can be maintained as closely as possible.

A special form of data input is utilized in line 1940 in order to gather the digitized Series 400 output as rapidly as possible. This transfer is an unformatted (NOFORMAT) word direct memory access (WDMA) input. By specifying NOFORMAT the data are sent and received in their internal binary form. Using NOFORMAT the number of words to be transferred must be specified; this is represented by the variable N. When the ENTER statement is called, the PCTL line is still in the high state and constitutes the issuance of a STEP/STROBE pulse. The Series 400 then converts one channel of data, the channel indicated by the channel address pointer. Channel 0 will be converted on the first STEP/STROBE pulse since the address pointer was reset to channel 0 when the Series 400 was set up for sequential sampling mode (line 1800). Following analog-to-digital conversion and placement of the data word on the interface cable lines DI0 - DI11, the Series 400 issues an EOC signal (low to high on the PFLG line). Since jumper 3 is installed in the interface, the incoming EOC signal causes the PCTL line to return to its high state (control set). This issues another STEP/STROBE pulse, which initiates another conversion cycle. The data word read at the end of each conversion cycle satisfies one count toward the count parameter N (line 1940). The self-triggering conversion cycles will continue until the number of data words read equals N. At this point the enter list (variable Dt$) is satisfied and the ENTER NOFORMAT statement is terminated.

Line-by-line execution proceeds to line 1950, which returns the program to the line following the one that was being executed when the interrupt request was received. This will be either line 1890 or 1900, and the endless loop execution will continue until another clock-generated interrupt request is received. The endless loop is automatically exited if 1400 data scans have been completed (array Dt$ is full, line 1930). If a test is completed before 1400 scans have been executed, the loop may be exited by pressing special function key K0, which was defined in line 1730. Immediately after data acquisition is complete, an end time reading is taken (lines 1960 and 1970). The actual time between scans is then calculated from the beginning and end times and the number of scans completed (line 2020).

The data in array Dt$ are still in an internal binary form and are not suitable for display or calculation. Each member of the character array Dt$ is a single binary character string that represents the readings taken from all the channels during a scan. Subprogram Convert uses a variable-to-variable transfer to convert the character strings into separate numeric data items. Data are stored, however, just as they are in array Dt$.

OPERATION

Basic Functioning

Instrumentation in the CIV may be used with or without the vehicle's engine running. For inside use or for performing system checks where running the engine is impractical, an extension cord can be used to provide the 110-V power requirements of the instrumentation. A receptacle is located on the far right side of the back of the vehicle, and a switch, located in the vehicle's rear compartment on the right side, is used for selecting inverter or shore (external) electrical supply. Receptacle and switch positions are shown in Figure 28. When operating from an external electrical supply, the instruments which require 12-V d.c. power are running off the vehicle's battery.

When using the inverter to supply electricity, the vehicle must be running before the invertor is switched on. The selector switch should then be moved from the center (off) to the inverter position.

Once the electrical supply for the vehicle has been established, power for any instrumentation is available at the power strip located inside the vehicle cab (Fig. 8). This outlet block contains an on-off switch, an indicator light and a circuit breaker. Switching the barrier strip on automatically turns on the Series 300 and 400 units. The computer has its own on-off switch located on its right side. The velocity signal conditioner switch is used to turn on the driver readout unit, both signal

Figure 28. External power receptacle and switch.

conditioners and the multiplexer. The fifth-wheel system is activated from the display unit's on-off switch (Fig. 13b).

Set-up for a test should include adjusting the excitation supply (10 V) to each load-cell channel (variable resistor R5, Fig. 18) and placing the remote-local switch (Fig. 19) and switches K101 - K104 in the desired positions (for local operation only, Fig. 19). The throughput-rate switches (Fig. 21) should also be set. With the power off, the last-channel switches (Fig. 20) should be set and the 98032A interface card plugged into the 9845 computer.

The actual test may now be started by latching the AUTOST key on the computer in the down postion and turning it on (with the master cartridge in tape drive T15 and a data tape in T14). *If the AUTOST key is not used*, the instruction GET "DATACQ:T15" followed by pressing the EXECUTE key will load the data acquisition program. When the program has been loaded, pressing the RUN key will begin the program. The same sequence can be used with GET "READ-2:T15" to load and run the read program.

Calibration procedures

To ensure that accurate force and speed readings are being obtained, several levels of system calibration must be regularly performed. These range from the readings which zero out the weight of each test tire and measure their rolling circumference to a whole system calibration which determines the accuracy of the shunt resistors and the fifth-wheel measurements. Calibration of the data acquisition equipment itself is covered by the appropriate manufacturer's manual.

In-field or pretest calibration is essentially a self-directed process performed by the Calibration subprogram. The program collects zero and shunt resistance values for the vertical force channels with the front of the vehicle elevated. Upon being lowered the vehicle is rocked back and forth by switching the gearshift between forward and reverse. It is then allowed to roll to a stop (with the transmission in neutral) and zero and shunt resistance readings are taken for the longitudinal and side force channels; zero readings are also taken for the velocity channels. The rocking procedure is performed to remove any "unnatural" forces developed when the tires were lowered back onto the pavement following vertical force channel sampling. The velocity channels are scaled by driving at a constant speed of 10 mph while data sampling occurs on those channels.

During the program-directed calibration procedure, the driver readout unit may be adjusted if necessary. When elevated (vertical channels zero) and after rolling back and forth (longitudinal, side and velocity channels zero), the zero-adjust resistors on the driver readout amplifier can be adjusted to yield a zero reading on the DPMs. Likewise, when shunt resistance is substituted into the bridge, the gain resistor of the amplifier may be adjusted to display the shunt resistance load values on the DPMs. The velocity channel resistors can be adjusted during the 10-mph run.

The driver readout unit can also be adjusted by switching the Series 300 to local operating mode and manually switching the shunt resistors in and out (switch K102, Fig. 19). (The zero for vertical channels still requires jacking the front of the vehicle off the ground.)

The subprogram finally calculates scaling factors and stores these and the zero readings in a file that begins with a C and includes the date and tire code. As previously mentioned, a new calibration file should be collected each time the front tires are changed (to zero out the weight of the tire), the inflation pressure of the shock absorbers is changed, or the system is turned on.

The whole system should be calibrated periodically (approximately every 100 hours of use) or whenever concerns about the validity of the data arise. Two forms of whole system calibration will be discussed; the first is perhaps better identified as a system adjustment.

The system adjustment is performed to obtain maximum sensitivity from the instrumentation. The Series 400 returns digital values (counts) in the range from -2048 to +2047. The system adjustment zeros and scales the incoming signals so that the expected range of these signals is spread over the largest portion of the numbers from -2048 to +2047 but does not fall outside them.

Lines 3730 - 3790 of DATACQ are included in the Calibration subprogram as comment statements (non-executed). By removing the leading exclamation point from each of these lines, running of the subprogram will generate a hard copy of the digital zero values. Also output is the shunt (calibration) value and the scale factor, which represents the number of pounds (or miles per hour) per digital count. Ideally channels 1 and 5 (vertical force) should have zero values near -2048 (or well into the negative numbers), since the vertical force varies between zero and approximately 2000 pounds (it does not go negative). The longitudinal and side forces are both two-directional forces, yielding positive and negative values. The side forces are symmetric, and thus the zero load reading should yield a digital count near zero. Longitudinal forces are not symmetric; generally force magnitudes in traction (positive) can range up to twice as much as resistance (negative) forces. Thus, the zero load count for longitudinal forces should be about -700. Zero load count values can be adjusted with resistor R7 on the strain-gage mode card (Fig. 18). Rereading the digital counts after adjusting the resistor is then accomplished by rerunning the Calibration subprogram.

Scaling the load-cell channels can only be done in integer multiples by changing the gain code (line 2350 of DATACQ) in the Series 400. This increases or decreases the sensitivity with which the Series 400 reads the input data, as shown in Table 2. (Caution: whenever the gain code in subprogram Calibration is changed [line 2350], it must also be changed in Scan [line 1630] to acquire meaningful data.)

The velocity channels have no voltage output when the vehicle is at rest. Thus, the Series 400 returns a digital count near zero for the zero velocity value. Once scaling (gain) is set for the load-cell channels, the velocity digital count can be checked for a speed of 10 mph from the matrix output of the shunt values for channels 4, 8, 10 and 11. The digital count for 10 mph can be adjusted with the knurled variable resistors (top row) on the front of the velocity signal conditioner. Since zero speed gives a count of zero, the maximum speed expected should be set equal to a count of 2047. The count which should be output from the calibration procedure (10 mph) can be found by multiplying the ratio of calibration speed to maximum expected speed by 2047.

The second form of whole system calibration is quite involved and should be performed annually. The procedure involves checking the accuracy of the shunt resistors and the fifth-wheel assembly. Since no variable scaling can be performed on the load-cell channels, the accuracy of the system depends entirely on the accuracy of the shunt resistance substitution. Table 1 lists the current values of the precision shunt resistors. This whole system calibration checks the accuracy of these values and changes them if necessary. The reason for including the fifth-wheel in the calibration is that it is used to scale all the other velocity channels. (The 10-mph speed maintained during subprogram Calibration is based on the fifth-wheel readout.)

Calibration of the fifth-wheel assembly involves operating it over an accurately measured course of at least one mile. The vehicle should be carefully aligned at the beginning and end course markers and the accumulated pulse counts read from the driver readout unit. Dividing the counts by 25 yields the distance in feet. If the measured and true distances vary by less than 0.2%, the fifth-wheel tire pressure can be varied to bring the two into agreement. Errors greater than 0.2% should be corrected by the manufacturer. The fifth-wheel speed is automatically calibrated when distance is calibrated, since a crystal clock is used for obtaining velocity.

To check the shunt resistor values, a special wheel has been constructed for calibrating the longitudinal and side forces (Fig. 29). When the calibration wheel is being used, the axle housing should be supported by a stable jack stand placed only slightly outside the centerline of the vehicle (toward the side with the calibration wheel). This allows the suspension system to be as uninhibited by the jack stand as possible. By pulling on the calibration wheel chain with an accurate load cell inserted in the force train, a known load can be applied along the longitudinal or

Figure 29. Shunt-resistor calibration wheel.

side directions. Care should be taken to ensure that the direction of pull is directly along the longitudinal or side axes. If the external load-cell reading differs from the value read out by the subprogram Rawdata of DATACO, then the value of the shunt resistor for the channel needs to be changed (lines 3460 - 3560 of subprogram Calibration).

If there is a disparity between the load applied to the wheel and the force value output by the CIV system, a check should be made to see that the external force is being applied exactly along the longitudinal or side axes. If a difference in values still exists, the shunt resistor value must be changed. This is accomplished by monitoring the output from the bridge through the upper set of jacks on the strain-gage mode card (Fig. 18). A voltmeter with 1-μV accuracy should be used to obtain 1-lb accuracy. With the Series 300 switched to local control, K102 activated (shunt resistor in bridge), and no forces acting on the calibration wheel, the bridge output can be read with the precision voltmeter. With switch K102 then set for normal operation, the force on the calibration wheel should be increased until the same bridge output is read on the voltmeter. The external load-cell output will then indicate the true value of the shunt resistor. This sequence can be repeated for the longitudinal and side channels.

A similar sequence, using a flat load cell, can be performed for calibrating the vertical force channels. In this case the vehicle retains its normal front wheels and tires. To ensure loading along the vertical axis, it is best if the external load cell is placed in a recess that allows the vehicle to drive directly onto it. If the external load-cell reading differs from that registered by the triaxial load cell, the vertical channel shunt resistor values must be corrected. Again, with no load on the vertical channels (tires elevated), the shunt resistor is placed in the bridge and the bridge output is read with a precision voltmeter. Returning to normal operation, the vehicle is rolled back over the external load cell. The axle must now be tied to the floor in such a way that additional vertical force can be applied to the wheel.

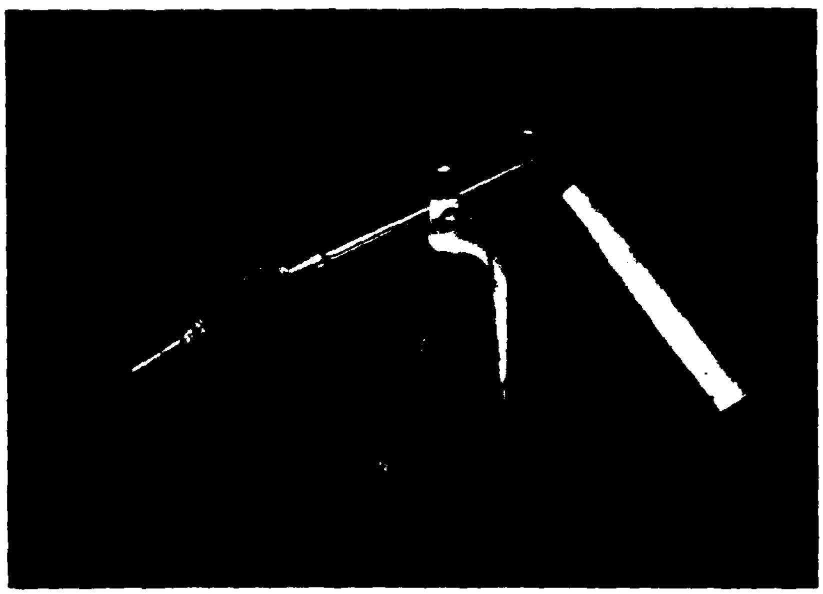
While the bridge output is monitored with the precision voltmeter, the vertical load is increased with a take-up device until the shunt resistance voltage appears across the bridge. At this point the reading on the external load cell represents the new value of the shunt resistor.

Evaluating the torque cell shunt resistor involves the same basic procedure as outlined for the triaxial load cells. However, an accurate external torque measuring device must be used on the rear propellor shaft to read the torque when the bridge output is equal to the shunt resistance value.

The procedures for re-evaluating the shunt resistance values must be performed carefully. The accuracy of the external load and torque measuring devices should be within 1% or less. (The triaxial load cells have an accuracy of better than 1%.) Alignment when applying external forces must be as exact as possible. Several repetitions of each step are also recommended; significant differences in repetition results should be scrutinized.

For ultimate accuracy the shunt resistor calibration sequence should be performed on an air-bearing plate. These devices, however, are not in

a. Axle grease recess location.



b. Grease gun.

Figure 30. Lubrication of the axle shaft.

great abundance and take a significant amount of time to learn to use. Three-dimensional air-bearing plates are nonexistent, although development is in the process. A two-dimensional plate can be used, though, but care must be taken to ensure that no load is being imparted in the third direction.

Maintenance

In addition to normal vehicular maintenance, which should be followed closely, the CIV requires special attention in certain areas. Since the vehicle spends a lot of time with the engine running but without accumulating many miles, the carburetor should be cleaned regularly. Periodically the vehicle should be driven for several miles at normal highway speeds to ensure lubrication of the drive train.

Of primary importance is the lubrication (greasing) of the axle shaft where it passes through the load cell. A grease recess has been machined into the steering universal joint in the piece that extends through the load cell (Fig. 30a). This recess can be accessed by turning the wheels their full amount and rotating the universal until the recess comes into view. A special grease-gun tip is necessary for lubrication (Fig. 30b). These shafts must be greased no less than following each full day of operation. All cable connections located under the vehicle should be regularly checked for corrosion and snugness of fit.

The tape drives of the minicomputer require frequent cleaning (every 8 hours of use) with the cleaning solution supplied by the manufacturer and a cotton tip applicator. Also, the air filters located on the underside of the computer, near the front, should be removed and cleaned periodically.

CONCLUSION

The CIV has been used by CRREL for gathering mobility data during the past two winters. Aside from the obvious interest in the interaction of the three mutually perpendicular forces at the tire contact path, several areas of mobility research have received emphasis. Most attention has been devoted to tire traction, with several techniques being used to generate traction data for many varied tire types on ice, snow and thawing soils. Numerous evaluation schemes have been applied to the data and relative performance levels compared. Along with this, operator dependence on traction test output is being studied.

Resistance tests have been used to compare various tire types on several cold regions materials, including low temperature, clear pavement. Using a single tire type, resistance tests have also been used to compare the resistance to motion offered by varieties of cold regions materials. These values have formed the beginning of a cold regions materials mobility data bank.

Although the CIV is regularly undergoing modifications, the bulk of the information contained in this report will remain unchanged. Anticipated changes include the addition of an automatic throttle-control device and the replacement of the fifth wheel with a radar speed-and-distance metering device. Additionally, a random-access mass storage device will probably be added to the data acquisition equipment to increase storage capacity and I/O speed. Changes to the software will undoubtedly take place on a regular basis, primarily in the data analysis sections. Any changes in the data acquisition portions of the program will be directed at improving the speed and efficiency of data sampling.

APPENDIX A: OPERATING MANUALS

Advanced Programming ROM Manual. Hewlett Packard Co., Part No. 09845-92065, Feb. 1980, 108 p.

BASIC Language Interfacing Concepts. Hewlett Packard Co., Part No. 09835-90600, Sept. 1979, 189 p.

Data Book USFS 3296 System. Nevada Automotive Test Center Project No. 20-17-70, June 1978.

Graphics ROM Manual. Hewlett Packard Co., Part No. 09845-91050, May 1979, 203 p.

I/O ROM Manual. Hewlett Packard Co., Part No. 09845-92060, Aug. 1980, 192 p.

Mass Storage ROM Manual. Hewlett Packard Co., Part No. 09845-92070, Feb. 1980, 132 p.

98032A 16-Bit Interface Installation and Service Manual. Hewlett Packard Co., Part No. 98032-90000, May 1979, 47 p.

98035A Real Time Clock Installation and Operation Manual. Hewlett Packard Co., Part No. 98035-90000, Feb. 1979, 73 p.

System 620, Series 300 Operation and Maintenance Manual. Neff Instrument Corp., Publication No. 620953, Sept. 1980, 57 p.

System 620, Series 400 Operation and Maintenance Manual. Neff Instrument Corp., Publication No. 620954, Nov. 1978, 149 p.

System 620 to H-P 9825, Interface Cable Connection Manual. Neff Instrument Corp., Publication No. 620079, Apr. 1979, 8 p.

System 45 Operating and Programming Manual. Hewlett Packard Co., Part No. 09845-92000, Feb. 1980, 302 p.

APPENDIX B: SCHEMATIC AND WIRING DIAGRAMS

The diagrams and schematics that follow are meant, when used with the manufacturer's manuals, to provide complete electronic coverage of the CIV. Most of the figures are referenced in the text; however, some which are not are included here for completeness. Pin assignments, connector labels and wiring color codes are also included where appropriate.

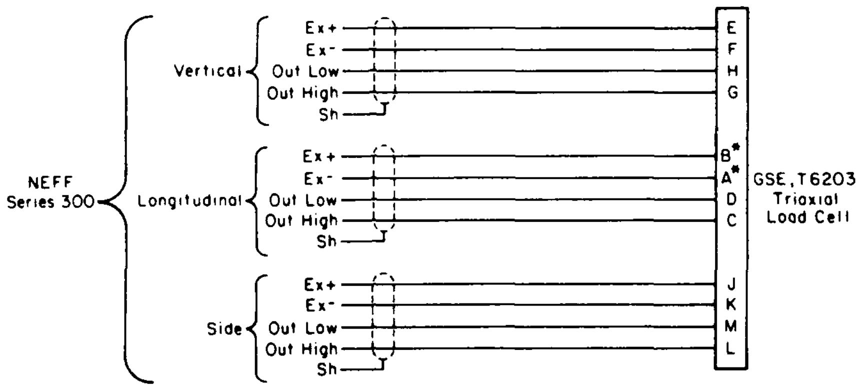


Figure B1. Wiring convention to and from the triaxial load cells. Color code: Ex+, red; Ex-, black; Out Low, white; Out High, green; Sh, stranded wire.
*The left-side load cell is depicted here; the right-side load cell is the same except that it has Ex- on pin B and Ex+ on pin A.

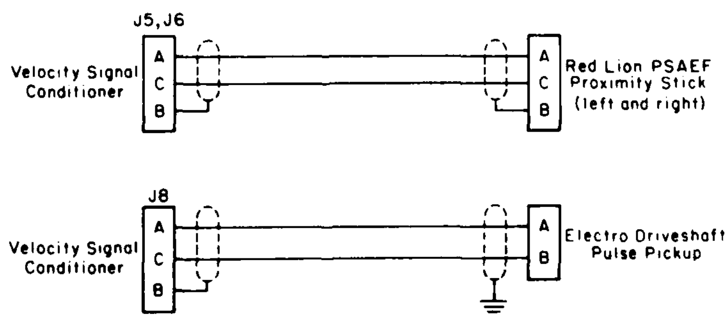


Figure B2. Wiring convention to and from the pulse pickups. Color code for J5, J6 and J8: A, red; B, stranded wire; C, black.

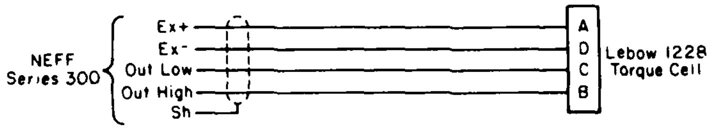


Figure B3. Wiring convention to and from the torque cell. Color code: Ex+, white; Ex-, green; Out Low, black; Out High, red; Sh, stranded wire.

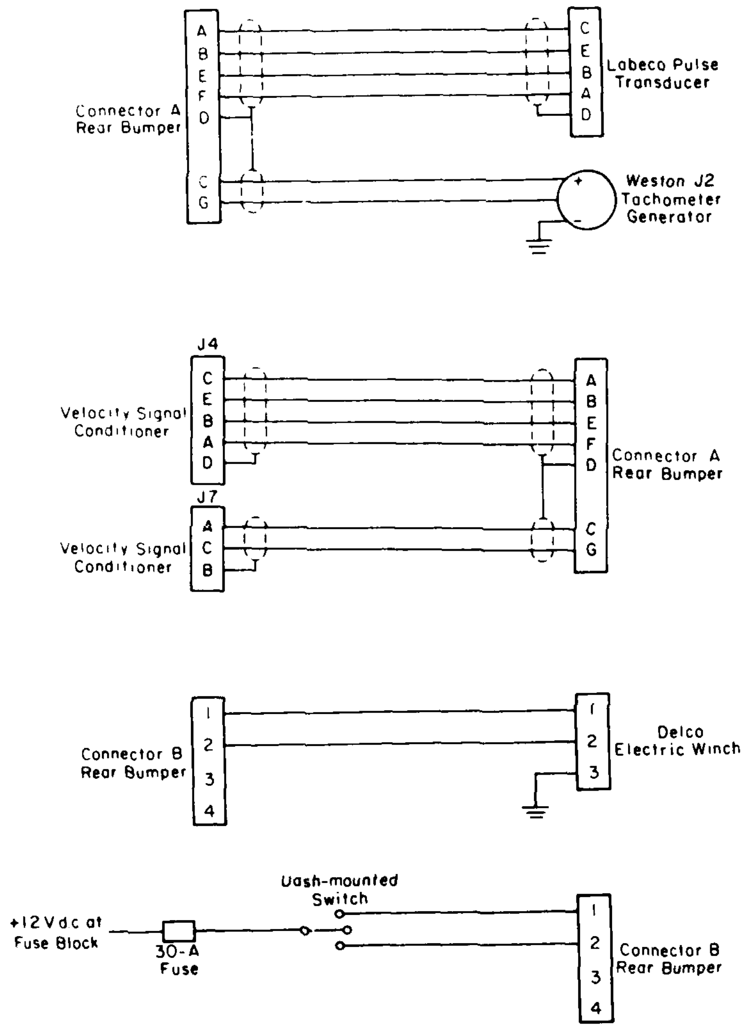


Figure B4. Wiring convention to and from the fifth-wheel assembly. Color code for connector A: A, white; B, green; C, red (large); D, stranded wire; E, black (small); F, red (small); G, black (large).
Color code for J4: A, red; B, black; C, white; D, stranded wire; E, green.
Color code for J7: A, red; B, stranded wire; C, black.

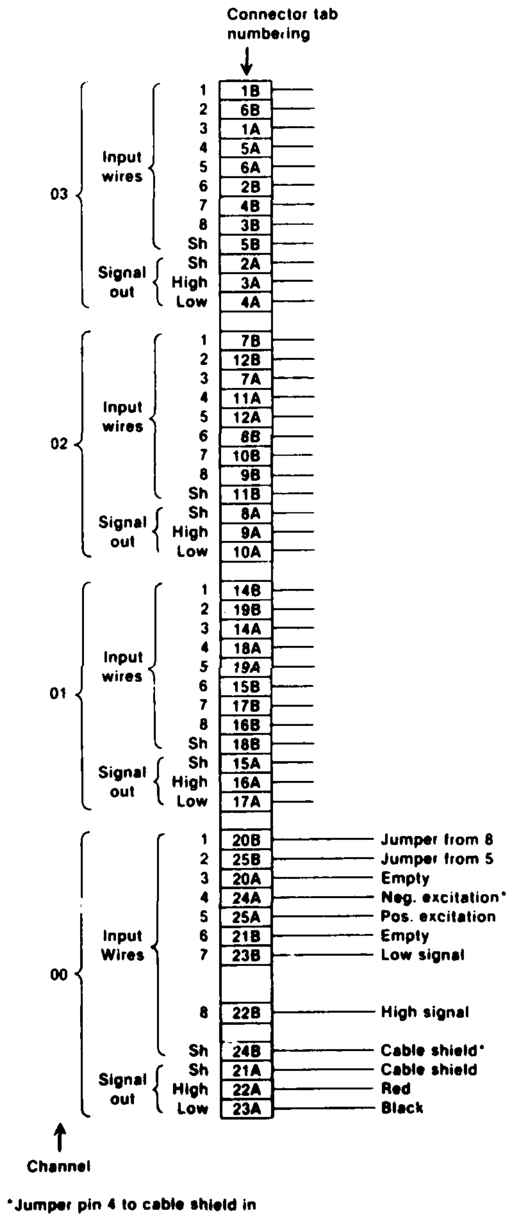


Figure B5. Input and output wiring to the Series 300 card edge connector.

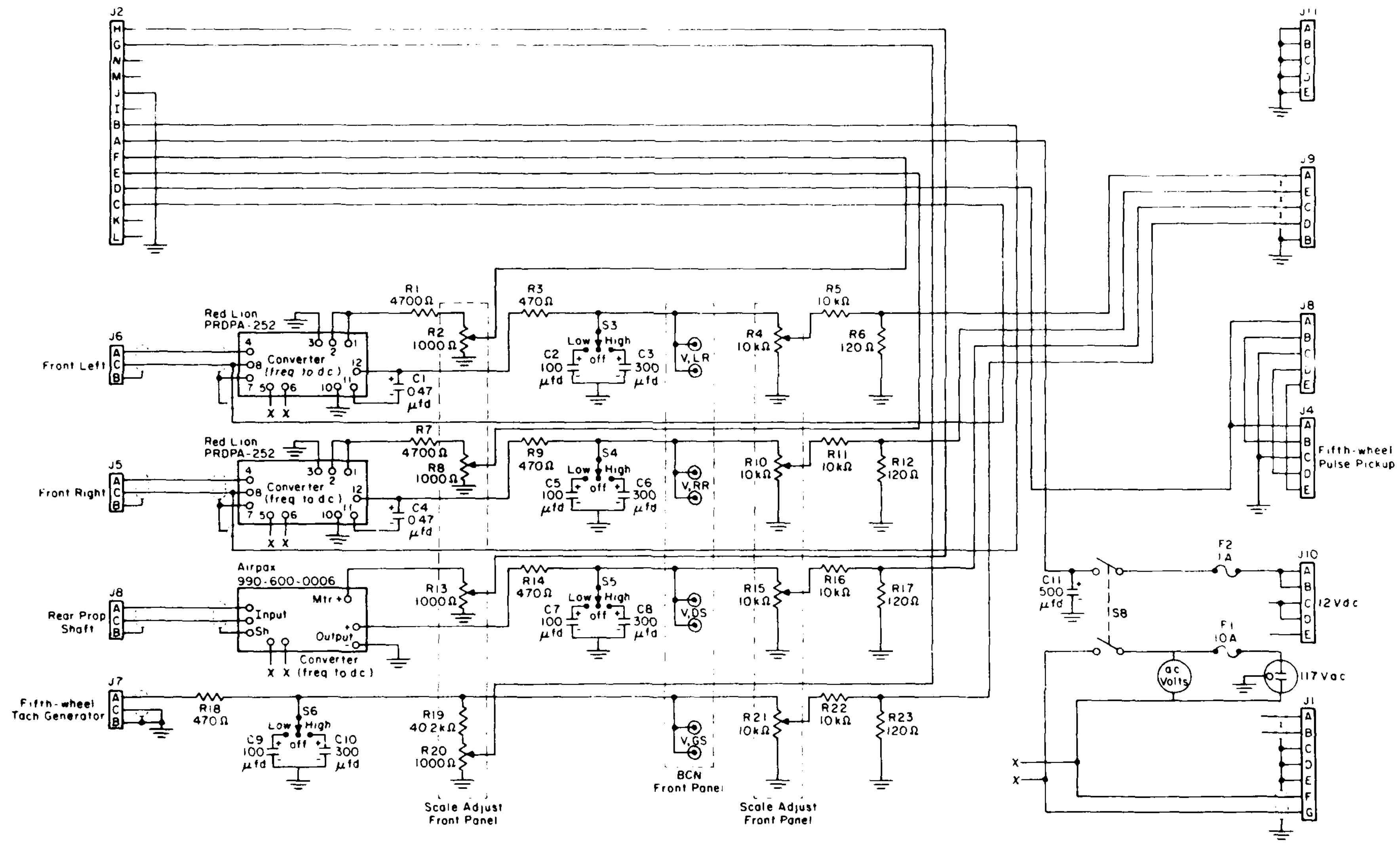


Figure 86. Schematic of the velocity signal conditioner.

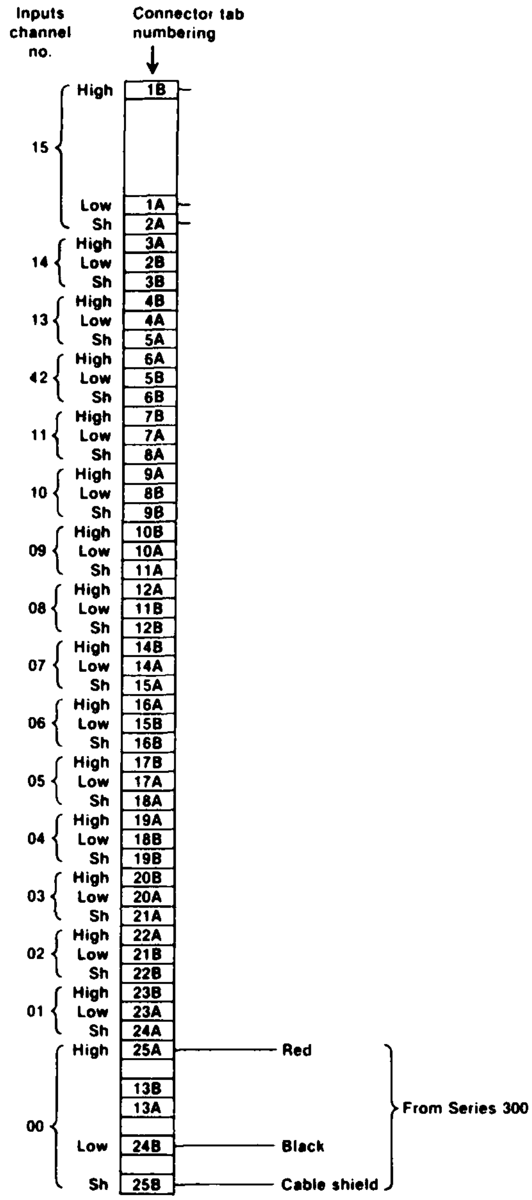


Figure B7. Input wiring to the Series 400 card edge connector.

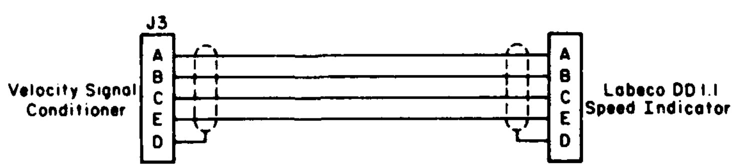


Figure B8. Input wiring to the fifth-wheel readout. Color code: A, red; B, black, C, white; D, stranded wire; E, green.

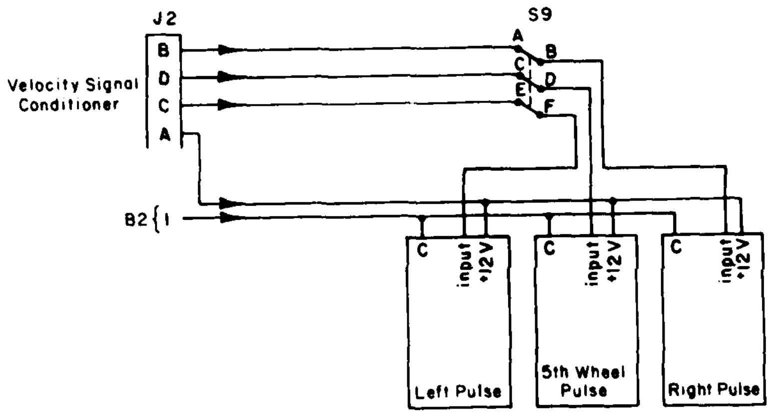


Figure B9. Input wiring to the pulse counters.

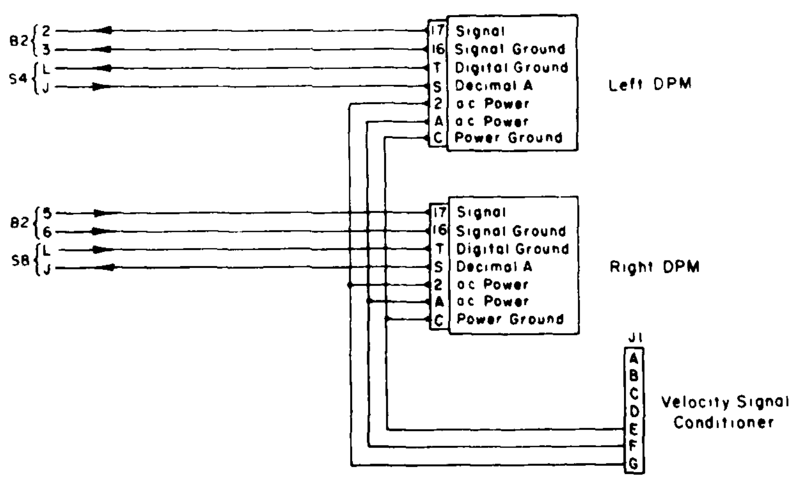


Figure B10. Input wiring to the digital panel meters.

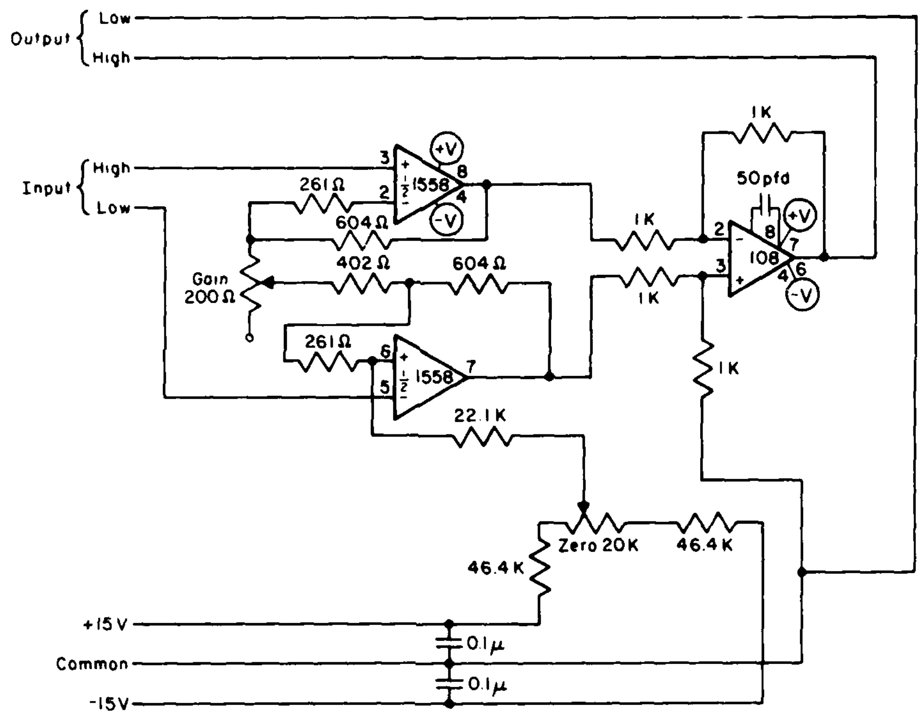


Figure B11. Selector switch wiring.

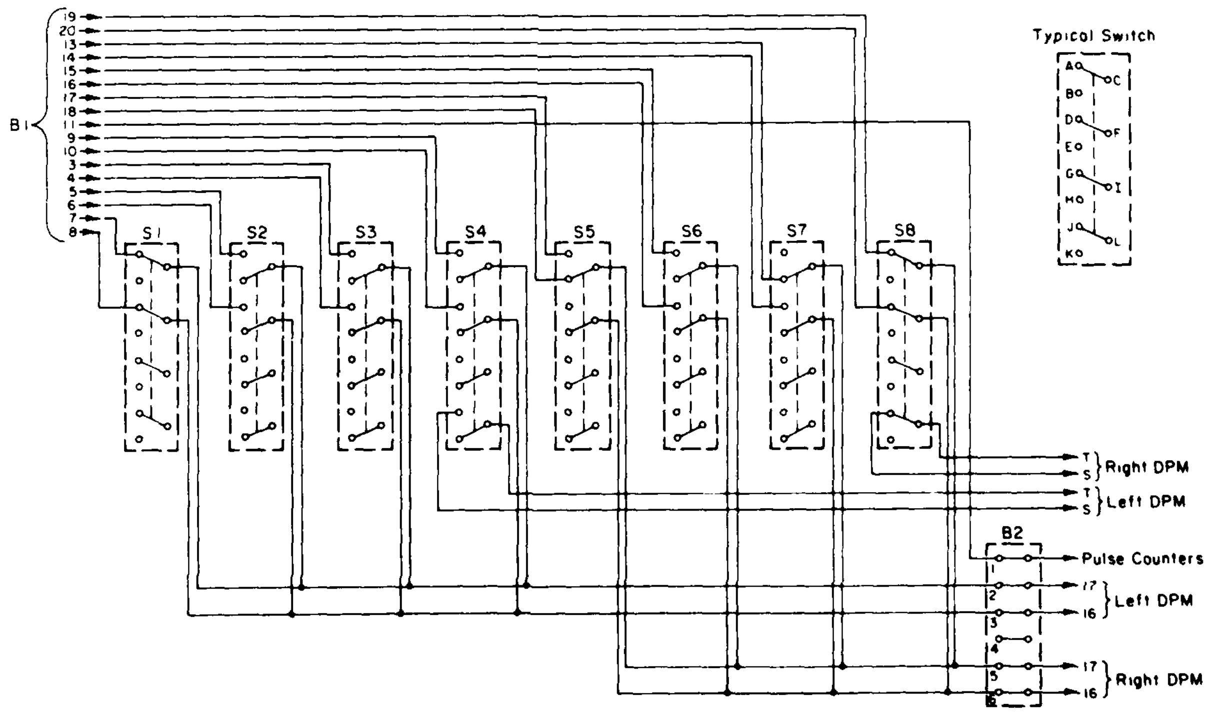


Figure B12. Typical channel from the eight-channel differential amplifier.

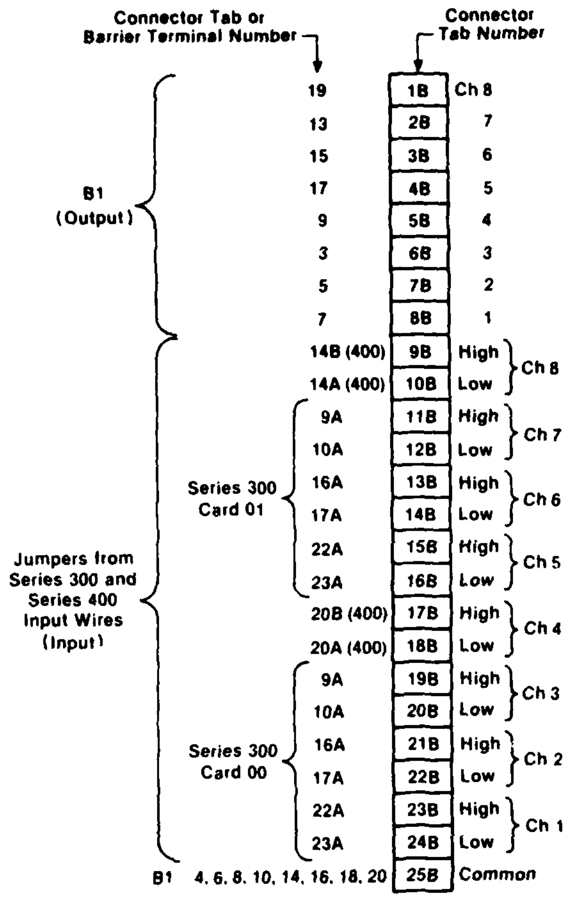


Figure B13. Input and output wiring to the driver readout differential amplifier.

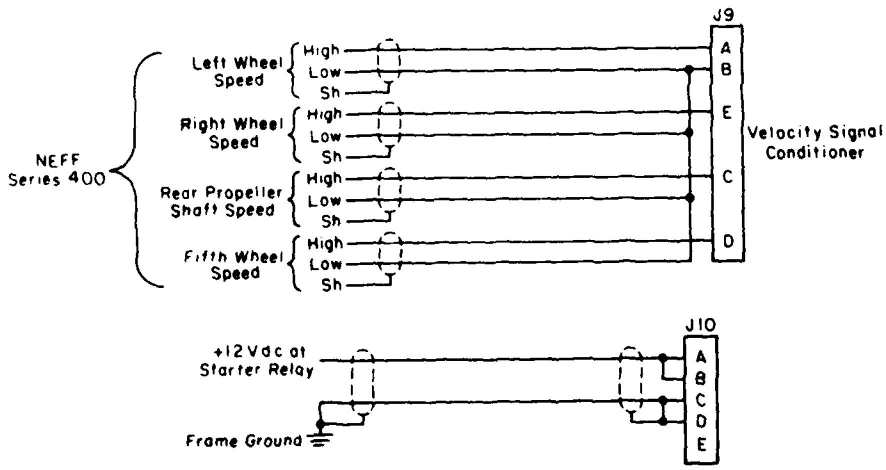


Figure B14. Wiring diagram for additional cables. Color code: High, red; Low, black; Sh, stranded wire.

APPENDIX C: COMPUTER PROGRAMS.

The two computer programs used with the CIV system, DATACO and READ-2, are listed in full in the following pages. An explanation of the coding (beyond that given in the main text) will not be included here. The appropriate manuals (Appendix A) and the program documentation should provide the user with an adequate programming explanation.

```
                              FILE NAME: DATACO:T15       DATE : 09:17:13:41
                                                          MAIN PROGRAM

10     !          (DATACO) DATA ACQISITION PROGRAM FOR
20     !                   INSTRUMENTED TEST VEHICLE.
30     !                   WRITTEN BY G BLAISDELL
40     !                   JANUARY 1981
50     !
60     !
70     !
80     !
90     MASS STORAGE IS ":T14"
100    OPTION BASE 1
110    Ascii=65
120    DIM List$(41)[41]
130    COM Loc$[50],T$(14)[30],Dt$(1400)[22],Dr(11),Tc$,G$,SHORT Di(4,1400),Mill
((1400),D(1400,11),Dist(2,1400),INTEGER L,Flag3
140    Reply=-3
150    GOTO 170
160    REDIM Dt$(1400),Mill(1400),Dist(2,1400),D(1400,11),Di(4,1400)
170    ENABLE
180    PRINTER IS 16
190    CAT TO List$(*),0,B
200    IF B=0 THEN GOTO 350
210    PRINT LIN(20)
220    PRINT CHR$(133);"          **** TAPE CARTRIDGE T14 IS FULL ****"
230    PRINT CHR$(27)&"E"
240    PRINT LIN(1),"    REMOVE FULL DATA CARTRIDGE FROM T14 AND INSERT NEW DATA
CARTRIDGE."
250    PRINT LIN(1),"    IF CARTRIDGE HAS BEEN USED BEFORE (ALREADY CONTAINS FIL
ES)"
260    PRINT LIN(1),"    DO NOT RE-INITIALIZE). IF TAPE HAS NOT BEEN USED BEFOR
E OR"
270    PRINT LIN(1),"    CONTAINS USELESS INFORMATION IT NEEDS TO BE INITIALIZED"
280    PRINT LIN(1),"    TYPE  '1' FOR INITIALIZATION.  0  TO JUST CONTINUE WITH
PROGRAM"
290    INPUT R
300    IF R  1 THEN GOTO 350
310    INITIALIZE ":T14"
320    PRINT LIN(20),CHR$(133);"       *** TAPE IS BEING INITIALIZED ***"
330    PRINT CHR$(27)&"E"
340    Flag3=0
350    IF Reply>0 THEN GOTO 400
360    INPUT "DO YOU WANT TO RUN CALIBRATION (0) OR A TEST (1)",R
370    IF R=1 THEN GOTO 400
380    CALL Calibration
390    IF Flag3=1 THEN GOTO 210
400    PRINT LIN(20)
410    INPUT "IS DOCUMENTARY DATA SAME AS PREVIOUS TEST (Y OR N)",Rpl$
420    IF Rpl$ "Y" THEN GOTO 500
430    Fr$=T$(2)[1,4]&CHR$(Ascii-1)
440    ON ERROR GOTO 460
450    GOTO 470
460    INPUT "ENTER PREVIOUS TEST FILE NAME (5 DIGITS)",Fr$
470    ASSIGN #6 TO Fr$
```

```
480   READ #6;Loc$,T$(*)
490   OFF ERROR
500   T$(1)="AA"
510   OUTPUT 9;"A"
520   OUTPUT 9;"R"
530   ENTER 9;T$(4)
540   T$(2)=T$(4)[1,2]&T$(4)[4,5]&CHR$(Ascii)
550   Ascii=Ascii+1
560   ! INPUT "ENTER NEW FILE NAME (MAX 5 CHAR,4 DIGIT MONTH & DAY + LETTER FOR
TEST NO.)",T$(2)
570   INPUT "ENTER TIRE INFLATION PRESSURE",T$(6)
580   T$(5)=Tc$
590   INPUT "ENTER TEST TYPE",T$(7)
600   T$(14)=G$
610   IF Fpl$="Y" THEN GOTO 1010
620   LINPUT "ENTER TEST LOCATION",Loc$
630   INPUT "AMBIENT TEMP(DEG C)",T$(3)
640   PRINT LIN(3),"SNOW - 1"
650   PRINT "ICE - 2"
660   PRINT "THAWING SOIL - 3"
670   PRINT "HARD SURFACE - 4",LIN(3)
680   ON ERROR GOTO 720
690   INPUT "SURFACE MATERIAL TYPE CODE",J
700   PRINT LIN(25)
710   ON J GOTO 740,810,880,950
720   PRINT ERRM$
730   GOTO 640
740   T$(8)="SNOW"
750   LINPUT "SNOW TYPE",T$(9)
760   INPUT "NOMINAL SNOW DEPTH(CM)",T$(10)
770   INPUT "NOMINAL SNOW DENSITY(G/CC)",T$(12)
780   INPUT "NOMINAL SNOW TEMP(DEG C)",T$(11)
790   INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",T$(13)
800   GOTO 1010
810   T$(8)="ICE"
820   LINPUT "SURFACE UNDERLYING ICE",T$(9)
830   INPUT "ICE THICKNESS(CM)",T$(10)
840   INPUT "ICE TEMP(DEG C)",T$(11)
850   INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",T$(13)
860   T$(12)="0"
870   GOTO 1010
880   T$(8)="THAWING_SOIL"
890   LINPUT "SOIL TYPE",T$(9)
900   INPUT "DEPTH OF THAWED LAYER(CM)",T$(10)
910   INPUT "THICKNESS OF FROZEN LAYER(CM)",T$(12)
920   INPUT "TEMP OF THAWED LAYER(CM)",T$(11)
930   INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",T$(13)
940   GOTO 1010
950   T$(8)="HARD_SURFACE"
960   LINPUT "SURFACE MATERIAL",T$(9)
970   INPUT "SURFACE TEMP(DEG C)",T$(11)
980   INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",T$(13)
990   T$(12)="0"
1000  T$(10)="NA"
1010  !
1020  PRINTER IS 0
1030  PRINT LIN(1),T$(2)
1040  PRINTER IS 16
1050  IMAGE @,
1060  PRINT USING 1050
1070  PRINT LIN(1),"FILE NAME:     ";T$(2)
1080  PRINT LIN(1),"LOCATION:     ";Loc$
1090  PRINT LIN(1),"AMBIENT TEMP:     ";T$(3);" DEG C"
1100  PRINT LIN(1),"DATE AND TIME:     ";T$(4)
1110  PRINT LIN(1),"TIRE CODE:     ";T$(5)
1120  PRINT LIN(1),"TIRE INFLATION PRESS:     ";T$(6);" psi"
1130  PRINT LIN(1),"TEST TYPE:     ";T$(7)
1140  PRINT LIN(1),"CALIBRATION FILE NAME:     ";T$(14)
1150  PRINT LIN(3),"TEST MATERIAL:     ";T$(8)
1160  PRINT LIN(1),"TYPE(OR UNDERLYING SURFACE):     ";T$(9)
1170  PRINT LIN(1),"DEPTH OR THICKNESS:     ";T$(10);" CM"
1180  PRINT LIN(1),"MATERIAL TEMP:     ";T$(11);" DEG C",LIN(1)
1190  IF T$(8)="SNOW" THEN PRINT "SNOW DENSITY:     ";T$(12);" G/CC"
1200  IF T$(8)="THAWING_SOIL" THEN PRINT "FROZEN LAYER THICK:     ";T$(12);" CM"
1210  PRINT LIN(1),"SOLAR INPUT (CLOUD COVER, SHADE)     ";T$(13);"%"
1220  LINPUT "DO YOU WISH TO CHANGE DOCUMENTARY DATA (Y OR N)?",Rpt$
1230  IF Rpt$="Y" THEN GOTO 500
1240  PRINT LIN(5),"REMARKS:"
1250  PRINTER IS 16
```

```
1260  CALL Scan
1270  REDIM Dt$(L),Dio(4,L),Milli(L),D(L,11),Dist(2,L)
1280  PRINT CHR$(27)&"E"
1290  Flag=0
1300  PRINTER IS 16
1310  PRINT LIN(20),"NUMBER OF SAMPLES TAKEN = ";L-1
1320  PRINT "                              STORE DATA  -  1"
1330  PRINT "                           VIEW RAW DATA  -  2"
1340  PRINT "                            TO PLOT DATA  -  3"
1350  PRINT "                            STOP PROGRAM  -  4"
1360  PRINT "  RUN ANOTHER TEST WITH SAME TIRE  -  5"
1370  PRINT "   CALIBRATION PROGRAM (NEW TIRE)  -  6"
1380  PRINT "  FIND AVE. MOTION RESIST. VALUES  -  7"
1390  PRINT "                FIND TRACTION VALUE  -  8"
1400  PRINT "             CALCULATE SLIP ENERGY  -  9"
1410  PRINT LIN(5)
1420  INPUT "WHICH ROUTINE DO YOU WISH (TYPE IN NUMBER CODE)? ",Reply
1430  IF Reply=1 THEN CALL Store
1440  IF Reply=4 THEN GOTO 1580
1450  IF Reply=5 THEN GOTO 160
1460  IF Reply=6 THEN CALL Calibration
1470  IF Flag3=1 THEN GOTO 210
1480  IF (Reply<>2) AND (Reply<>3) AND (Reply<>7) AND (Reply<>8) AND (Reply<>9)
THEN GOTO 1300
1490  Flag=Flag+1
1500  IF Flag>1 THEN GOTO 1520
1510  CALL Convert
1520  IF Reply=2 THEN CALL Rawdata
1530  IF Reply=3 THEN CALL Plots
1540  IF Reply=7 THEN CALL Average
1550  IF Reply=8 THEN CALL Traction
1560  IF Reply=9 THEN CALL Slip_energy
1570  GOTO 1300
1580  END
1590  SUB Scan
1600  OVERLAP
1610  OPTION BASE 1
1620  COM Loc$[50],T$(14)[30],Dt$(*),Dt(11),Tc$,G$,SHORT Dio(*),Milli(*),D(*),Di
st(*),INTEGER L,Flag3
1630  Gain=10
1631  T=100
1632  GOTO 1650
1640  INPUT "SCAN INTERVAL IN MILLISECONDS (MINIMUM 15ms (=66 SAMPLES PER SECOND
))",T
1650  N=11
1660  CONTROL MASK 6;0
1670  CARD ENABLE 6
1680  OUTPUT 6 WHS USING "#,W";15
1690  OUTPUT 9;"A"
1700  OUTPUT 9;"U1=O1,U2=I2"
1710  L=0
1720  PRINT LIN(50),CHR$(133);"               **** TO STOP DATA ACQUISITION PRESS K
EY K0 ****                 "
1730  ON KEY #0,15 GOTO 1960
1740  ON INT #9,8 GOSUB Sample
1750  CONTROL MASK 9;128
1760  OUTPUT 9;"B U1P",T
1770  CARD ENABLE 9
1780  CONTROL MASK 6;1
1790  CARD ENABLE 6
1800  OUTPUT 6 WHS USING "#,W";-32768+Gain*2048
1810  CONTROL MASK 6;33
1820  CARD ENABLE 6
1830  PRINT LIN(8)
1840  INPUT "                         TO START DATA ACQUISITION PRESS CONT
 ",Cont
1850  OUTPUT 9;"U1D 20"
1860  OUTPUT 9;"U1G,U2G"
1870  OUTPUT 9;"U2V"
1880  ENTER 9;Begintime
1890  REM
1900  GOTO 1890
1910 Sample:    CARD ENABLE 9
1920            L=L+1
1930            IF L>1398 THEN GOTO 1960
1940            ENTER 6 WDMA N NOFORMAT;Dt$(L)
1950            RETURN
1960  OUTPUT 9;"U2V"
1970  ENTER 9;Endtime
1980  PRINT CHR$(27)&"E"
```

```
1990  PRINT LIN(50),TAB(16),CHR$(132);"DATA ACQUISITION COMPLETED"
2000  DISABLE
2010  REDIM Dt$(L),Milli(L),Dist(2,L),D(L,11)
2020  Scantime=(Endtime-Begintime)/L
2030  Milli(1)=Scantime
2040  FOR I=2 TO L
2050  Milli(I)=Milli(I-1)+Scantime
2060  NEXT I
2070  WAIT 3000
2080  PRINT CHR$(27)&"E"
2090  SERIAL
2100  SUBEND
2110  SUB Store
2120  OPTION BASE 1
2130  COM Loc$[50],T$(14)[30],Dt$(*),Dr(11),Tc$,G$,SHORT Dv(*),Milli(*),D(*),Di
st(*),INTEGER L,Flag3
2140  ON ERROR GOTO 2200
2150  Phurec=1.3*(INT((L*24+L*2)/256)+INT((L*24+L*2)/65536)+5)
2160  CREATE T$(2),Phurec
2170  ASSIGN #4 TO T$(2)
2180  PRINT #4;Loc$,T$(*),L,Dt$(*),Milli(*)
2190  GOTO 2250
2200  IF ERRN<>54 THEN GOTO 2240
2210  DISP TAB(10),CHR$(129);"*** FILE HAS ALREADY BEEN STORED ***"
2220  WAIT 3500
2230  GOTO 2250
2240  PRINT ERRM$
2250  SUBEND
```

SUBPROGRAM Calibration

```
2260  SUB Calibration
2270  OPTION BASE 1
2280  DIM Zer(30,11),Shnt(30,11),S(11),Z(11),Scale(11),List$(37)[41]
2290  COM Loc$[50],T$(14)[30],Dt$(*),Dr(11),Tc$,G$,SHORT Dv(*),Milli(*),D(*),Di
st(*),INTEGER L,Flag3
2300  CAT TO Lfst$(*),0,B
2310  IF B=0 THEN GOTO 2330
2320  GOTO 3810
2330  MASS STORAGE IS ":T14"
2340  PRINTER IS 16
2350  Gain=10
2360  INPUT "ENTER TIRE CODE (ONE LETTER)",Tc$
2370  PRINT LIN(20)," TO BEGIN CALIBRATION SEQUENCE EQUIPMENT SHOULD BE"
2380  PRINT "TURNED ON FOR ABOUT 15 MINUTES.  JACK FRONT END CLEAR"
2390  PRINT "      OF GROUND. WHEN COMPLETE PRESS CONTINUE"
2400  INPUT R$
2410  PRINT LIN(20),TAB(13),CHR$(134);"*** DATA ACQUISITION IN PROGRESS ***"
2420  CONTROL MASK 6;0
2430  CARD ENABLE 6
2440  OUTPUT 6 WHS USING "#,W";15
2450  CONTROL MASK 6;1
2460  CARD ENABLE 6
2470  FOR I=1 TO 30
2480  FOR J=1 TO 5 STEP 4
2490  OUTPUT 6 WHS USING "#,W";Gain*2048+(J-1)
2500  ENTER 6 WHS USING "#,W";Zer(I,J)
2510  NEXT J
2520  NEXT I
2530  CONTROL MASK 6;0
2540  CARD ENABLE 6
2550  OUTPUT 6 WHS USING "#,W";13
2560  CONTROL MASK 6;1
2570  CARD ENABLE 6
2580  FOR I=1 TO 30
2590  FOR J=1 TO 5 STEP 4
2600  OUTPUT 6 WHS USING "#,W";Gain*2048+(J-1)
2610  ENTER 6 WHS USING "#,W";Shnt(I,J)
2620  NEXT J
2630  NEXT I
2640  PRINT CHR$(27)&"E"
2650  PRINT LIN(20)," LOWER FRONT END TO GROUND AND ROLL VEHICLE ALTERNATELY"
2660  PRINT " FORWARD AND BACK BY USING THE FORWARD AND REVERSE GEARS"
2670  PRINT " DO NOT USE ANY BRAKES IN BETWEEN AND ALLOW THE VEHICLE"
2680  PRINT "  TO ROLL TO A STOP (VEHICLE IN NEUTRAL,5th WHEEL DOWN)"
2690  PRINT "                   PRESS CONT WHEN READY"
2700  INPUT R$
```

```
2710  PRINT LIN(20),TAB(13),CHR$(134);"*** DATA ACQUISITION IN PROGRESS ***"
2720  CONTROL MASK 6;0
2730  CARD ENABLE 6
2740  OUTPUT 6 WHS USING "#,W";15
2750  CONTROL MASK 6;1
2760  CARD ENABLE 6
2770  OUTPUT 6 WHS USING "#,W";-32768+Gain*2048
2780  CONTROL MASK 6;33
2790  CARD ENABLE 6
2800  FOR I=1 TO 30
2810  FOR J=1 TO 11
2820  IF J=1 THEN GOTO 2860
2830  IF J=5 THEN GOTO 2860
2840  ENTER 6 WHS USING "#,W";Zer(I,J)
2850  GOTO 2870
2860  ENTER 6 WHS USING "#,W";Dum
2870  NEXT J
2880  NEXT I
2890  CONTROL MASK 6;0
2900  CARD ENABLE 6
2910  OUTPUT 6 WHS USING "#,W";13
2920  CONTROL MASK 6;1
2930  CARD ENABLE 6
2940  OUTPUT 6 WHS USING "#,W";-32768+Gain*2048
2950  CONTROL MASK 6;33
2960  CARD ENABLE 6
2970  FOR I=1 TO 30
2980  FOR J=1 TO 11
2990  IF J=1 THEN GOTO 3030
3000  IF J=5 THEN GOTO 3030
3010  ENTER 6 WHS USING "#,W";Shnt(I,J)
3020  GOTO 3040
3030  ENTER 6 WHS USING "#,W";Dum
3040  NEXT J
3050  NEXT I
3060  CONTROL MASK 6;0
3070  CARD ENABLE 6
3080  OUTPUT 6 WHS USING "#,W";15
3090  CONTROL MASK 6;1
3100  CARD ENABLE 6
3110  PRINT CHR$(27)&"E"
3120  PRINT LIN(20)," FOR CALIBRATION OF VELOCITIES, LOWER 5th WHEEL AND"
3130  PRINT " DRIVE IN A STRAIGHT LINE ON A HARD SURFACE AT 10mph"
3140  PRINT " (AS READ ON LABECO DD-1.1). IF VELOCITIES READ ON "
3150  PRINT " DPM ARE NOT ACCURATE, MAKE POT ADJUSTMENTS BEFORE "
3160  PRINT " PROCEEDING FURTHER IN PROGRAM. WHEN READY TO CAL-"
3170  PRINT " IBRATE (AT 10mph AS CLOSE AS POSSIBLE) PRESS CONT"
3180  INPUT R$
3190  PRINT LIN(20),TAB(13),CHR$(134);"*** DATA ACQUISITION IN PROGRESS ***"
3200  FOR I=1 TO 30
3210  FOR J=4 TO 12 STEP 4
3220  IF J=12 THEN J=11
3230  OUTPUT 6 WHS USING "#,W";Gain*2048+(J-1)
3240  ENTER 6 WHS USING "#,W";Shnt(I,J)
3250  NEXT J
3260  NEXT I
3270  PRINT CHR$(27)&"E"
3280  PRINT LIN(20),"          *** VELOCITY RUN FINISHED ***"
3290  PRINT LIN(3)," IF YOU FEEL VELOCITY VARIED TOO MUCH DURING RUN AND WISH"
3300  PRINT "       TO DO OVER , INPUT '1'. IF NOT INPUT  0'."
3310  INPUT Rpl
3320  IF Rpl=1 THEN GOTO 3110
3330  PRINT LIN(20)
3340  MAT Zt=ZER
3350  MAT St=ZER
3360  FOR J=1 TO 11
3370  FOR I=5 TO 30
3380  Zt(J)=Zt(J)+Zer(I,J)
3390  St(J)=St(J)+Shnt(I,J)
3400  NEXT I
3410  NEXT J
3420  FOR J=1 TO 11
3430  Zt(J)=Zt(J)/26
3440  St(J)=St(J)/26
3450  NEXT J
3460  Scale(1)=2124/(St(1)-Zt(1))
3470  Scale(2)=2001/(St(2)-Zt(2))
3480  Scale(3)=1992/(St(3)-Zt(3))
3490  Scale(4)=10/(St(4)-Zt(4))
```

```
3500  Scale(5)=2184/(St(5)-Zt(5))
3510  Scale(6)=2011/(St(6)-Zt(6))
3520  Scale(7)=2108/(St(7)-Zt(7))
3530  Scale(8)=10/(St(8)-Zt(8))
3540  Scale(9)=594/(St(9)-Zt(9))
3550  Scale(10)=10/(St(10)-Zt(10))
3560  Scale(11)=10/(St(11)-Zt(11))
3570  OUTPUT 9;"A"
3580  OUTPUT 9;"R"
3590  ENTER 9;T$
3600  D$=T$[1,2]&T$[4,5]
3610  ON ERROR GOTO 3630
3620  GOTO 3680
3630  IF ERRN<>54 THEN GOTO 3670
3640  PRINT ERRM$
3650  INPUT "PRESS CONT TO RESUME",Dumm$
3660  GOTO 3690
3670  INPUT "ENTER 4 DIGIT DATE (MONTH : DAY) ",D$
3680  G$="C"&D$&Tc$
3690  CREATE G$,1
3700  ASSIGN #6 TO G$
3710  OFF ERROR
3720  PRINT #6;Zt(*),Scale(*)
3730      PRINTER IS 0
3740      PRINT LIN(4),G$
3750      PRINTER IS 16
3760      MAT PRINT Zt
3770      MAT PRINT St
3780      MAT PRINT Scale
3790      PRINTER IS 16
3800  GOTO 3820
3810  Flag3=1
3820  SUBEND
```

SUBPROGRAM Convert

```
3830  SUB Convert
3840  PRINT LIN(20)
3850  DISP TAB(10),CHR$(132);"DATA CONVERSION IN PROGRESS"
3860  OPTION BASE 1
3870  DIM Zt(11),Scale(11)
3880  COM Loc$[50],T$(14)[30],Dt$(*),Dt(11),Tc$,G$,SHORT Dtt(*),Mill(*),D(*),Dt
s(*),INTEGER L,Flag3
3890  PRINTER IS 16
3900  ASSIGN #7 TO T$(14)
3910  READ #7;Zt(*),Scale(*)
3920  FOR I=1 TO L-1
3930  ENTER Dt$(I) USING "#,W";Dt(*)
3940  FOR K=1 TO 11
3950  D(I,K)=(BINCMP(Dt(K))-Zt(K))*Scale(K)
3960  NEXT K
3970  NEXT I
3980  PRINT CHR$(27)&"E"
3990  SUBEND
```

SUBPROGRAM Rawdata

```
4000  SUB Rawdata
4010  OPTION BASE 1
4020  COM Loc$[50],T$(14)[30],Dt$(*),Dt(11),Tc$,G$,SHORT Dtt(*),Mill(*),D(*),Dt
s(*),INTEGER L,Flag3
4030  INPUT "HARD COPY OR ON CRT (H OR C)",Ppl$
4040  PRINTER IS 16
4050  IF Ppl$="H" THEN PRINTER IS 0
4060  IMAGE 1X,"LV",5X,"LL",5X,"LS",5X,"LVI",7X,"RV",5X,"RL",5X,"RS",5X,"RVI",6X
,"SVI",4X,"Mill",
4070  IMAGE #,4D,3X
4080  IMAGE #,3X,4D,3X
4090  IMAGE #,DD.D,3X
4100  IMAGE #,2X,DD.D,3X
4110  IMAGE #,DDDDDD.D
4120  IMAGE /,20X
4130  PRINT CHR$(27)&"H"
4140  PRINT USING 4060
4150  PRINT CHR$(27)&"1"
4160  FOR J=1 TO L-1
4170  PRINT USING 4120
```

```
4180  FOR K=1 TO 8
4190  IF K=5 THEN GOTO 4230
4200  IF (K=4) OR (K=8) THEN GOTO 4250
4210  PRINT USING 4070;D(J,K)
4220  GOTO 4260
4230  PRINT USING 4080;D(J,K)
4240  GOTO 4260
4250  PRINT USING 4090;D(J,K)
4260  NEXT K
4270  PRINT USING 4100;D(J,11)
4280  PRINT USING 4110;Mill(J)
4290  NEXT J
4300  PRINT CHR$(27)&"m"
4310  PRINT LIN(3)
4320  SUBEND
```

SUBPROGRAM Average

```
4330  SUB Average
4340  OPTION BASE 1
4350  DIM Ave(8),A(L+1),Prcnt(8)
4360  COM Loc$[50],T$(14)[30],D$(*),Dt(11),Tc$,G$,SHORT D(*,*),Mill(*),D(*),D
st(*),INTEGER L,Flag3
4370  MAT Ave=ZER
4380  PRINTER IS 16
4390  PRINT LIN(20)
4400  PRINT LIN(20),"       VERTICAL - 1"
4410  PRINT "  LONGITUDINAL - 2"
4420  PRINT "          SIDE - 3"
4430  PRINT "      VELOCITY - 4"
4440  PRINT LIN(5)
4450  INPUT "CHOOSE CODE FOR CHANNEL TO BE AVERAGED ",Ch
4460  PRINT LIN(20)
4470  PRINT "       WHAT PERCENT OF THE DATA POINTS DO YOU WANT AVERAGED ?"
4480  PRINT LIN(2),"ANYTHING LESS THAN 100% WILL AVERAGE THE UPPER (ABSOLUTE VAL
UE) PERCENT CHOSEN"
4490  INPUT Prcnt(Ch)
4500  Prcnt(Ch+4)=Prcnt(Ch)
4510  PRINT LIN(20),"                         I M WORKING"
4520  FOR G=Ch TO Ch+4 STEP 4
4530  FOR H=1 TO L-1
4540  A(H)=D(H,G)
4550  NEXT H
4560  IF Prcnt=100 THEN GOTO 4680
4570  MAT SORT A
4580  Sum2=0
4590  FOR P=1 TO L/20
4600  Sum2=Sum2+A(P)
4610  NEXT P
4620  Aver=Sum2/(L/20)
4630  IF Aver<0 THEN GOTO 4680
4640  FOR H2=1 TO L-1
4650  A(H2)=ABS(D(H2,G))
4660  NEXT H2
4670  MAT SORT A
4680  Sum1=0
4690  Count=INT(Prcnt(Ch)/100*(L-1))
4700  IF Count<1 THEN Count=1
4710  FOR P=L-Count TO L-1
4720  Sum1=Sum1+A(P)
4730  NEXT P
4740  Ave(G)=Sum1/Count
4750  NEXT G
4760  PRINT LIN(20)
4770  INPUT "     DO YOU WANT TO CALCULATE ANY OTHER AVERAGES (Y OR N)?",Over$
4780  IF Over$="Y" THEN GOTO 4380
4790  INPUT "DO YOU WANT THE OUTPUT ON THE CRT OR A HARD COPY (C OR H)?",P$
4800  IF P$<>"H" THEN GOTO 4830
4810  PRINTER IS 0
4820  GOTO 4840
4830  PRINTER IS 16
4840  INPUT "DO YOU WANT TO SUPPRESS THE HEADING (DOCUMENTARY DATA) (Y OR N)?",Pp
$
4850  IF Pp$="Y" THEN GOTO 4930
4860  PRINT LIN(5)
```

```
4870  PRINT USING 5050;Loc$
4880  PRINT USING 5060;"FILE ";T$(2);T$(7);" TEST"
4890  PRINT USING 5060;"TIRE ";T$(5);T$(6);" psi"
4900  PRINT USING 5070;"MATERIAL: ";T$(8)
4910  PRINT USING 5070;T$(10);" CM THICKNESS"
4920  PRINT USING 5060;T$(12);" g cc";T$(11);" DEG C (AMBIENT)"
4930  PRINT LIN(3)
4940  FOR I=1 TO 8
4950  IF Ave(I)=0 THEN GOTO 5090
4960  Sd$="LEFT "
4970  IF I>4 THEN Sd$="RIGHT "
4980  Unit$=" LBS"
4990  IF (I=4) OR (I=8) THEN Unit$=" MPH"
5000  IF (I=1) OR (I=5) THEN Ch$="VERTICAL"
5010  IF (I=2) OR (I=6) THEN Ch$="LONGITUDINAL"
5020  IF (I=3) OR (I=7) THEN Ch$="SIDE"
5030  IF (I=4) OR (I=8) THEN Ch$="VELOCITY"
5040  PRINT USING 5080;"AVERAGE OF UPPER ";Frcnt(I);"% OF DATA - ";Sd$;Ch$;" - "
;Ave(I);Unit$
5050  IMAGE K
5060  IMAGE 2(K),4X,2(K)
5070  IMAGE 3(K)
5080  IMAGE  K,DDD.D,4(K),DDDD.D,K
5090  NEXT I
5100  IF R$="H" THEN GOTO 5130
5110  PRINT LIN(5)
5120  INPUT " PRESS CONT TO RESUME",Dum
5130  SUBEND
5140  SUB Slip_energy
5150  OPTION BASE 1
5160  DIM Slipen(2,L)
5170  COM Loc$[50],T$(14)[30],Dt$(*),Dr(11),Tc$,G$,SHORT Dv(*),Mill(*),D(*),Di
st(*),INTEGER L,Flag3
5180  Flg1=0
5190  Flg2=0
5200  Cnt=0
5210  IF T$(7)="TRACTION" THEN GOTO 5280
5220  PRINT TAB(10),CHR$(132);"*** FILE INDICATES THIS IS NOT A TRACTION TEST **
*"
5230  PRINT CHR$(128)
5240  PRINT LIN(2),"DO YOU STILL WANT AN INTEGRATION OF THE LONGITUDINAL FORCE-D
ISTANCE CURVE"
5250  PRINT TAB(30),"(Y OR N)"
5260  INPUT R$
5270  IF R$<>"Y" THEN GOTO 5690
5280  INPUT "DO YOU WANT THE OUTPUT ON THE CRT (C) OR A HARD COPY (H)?",Rpl$
5290  PRINT LIN(20),TAB(30),"I'M WORKING"
5300  PRINT LIN(5)
5310  IF Rpl$<>"H" THEN GOTO 5340
5320  PRINTER IS 0
5330  GOTO 5350
5340  PRINTER IS 16
5350  PRINT LIN(2)
5360  MAT Dist=ZER
5370  Cnt=Cnt+1
5380  IF Cnt=3 THEN GOTO 5670
5390  IF Cnt=2 THEN GOTO 5470
5400  FOR I=2 TO L-1
5410  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,4)+D(I-1,4))/2)*((Mill(I)-Mill(I-1
))/1000)
5420  Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,8)+D(I-1,8))/2)*((Mill(I)-Mill(I-1
))/1000)
5430  NEXT I
5440  PRINT LIN(2),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5450  PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
5460  GOTO 5540
5470  MAT Dist=ZER
5480  FOR I=2 TO L-1
5490  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((Mill(I)-Mill(I
-1))/1000)
5500  Dist(2,I)=Dist(1,I)
5510  NEXT I
5520  PRINT LIN(2),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5530  INPUT "PRESS CONT TO RESUME",Dum
5540  MAT Slipen=ZER
5550  FOR I=2 TO L-1
5560  Slipen(1,I)=Slipen(1,I-1)+(D(I,2)+D(I-1,2))/2*(Dist(1,I)-Dist(1,I-1))
5570  Slipen(2,I)=Slipen(2,I-1)+(D(I,6)+D(I-1,6))/2*(Dist(2,I)-Dist(2,I-1))
5580  NEXT I
5590  IF Cnt=2 THEN GOTO 5640
```

```
5600  IMAGE /K,DDDDDD.D,K
5610  PRINT USING 5600;"LEFT WHEEL ENERGY INPUT = ";Slipen(1,L-1);" FT-LBS"
5620  PRINT USING 5600;"RIGHT WHEEL ENERGY INPUT = ";Slipen(2,L-1);" FT-LBS"
5630  GOTO 5660
5640  PRINT USING 5600;"VEHICLE DISTANCE BASED ENERGY(LEFT SIDE) = ";Slipen(1,L-
1);" FT-LBS"
5650  PRINT USING 5600;"VEHICLE DISTANCE BASED ENERGY(RIGHT SIDE) = ";Slipen(2,L
-1);" FT-LBS"
5660  GOTO 5370
5670  PRINTER IS 16
5680  INPUT "PRESS CONT TO RESUME",Dum
5690  SUBEND
```

SUBPROGRAM Traction

```
5700  SUB Traction
5710  OPTION BASE 1
5720  COM Loc$[50],T$(14)[30],Dt$(*),Dt(11),Tc$,G$,SHORT Div(*),Mill(*),D(*),Di
s(*),INTEGER L,Flag3
5730  IF T$(7)="TRACTION" THEN GOTO 5810
5740  PRINT PAGE,CHR$(132),"**** FILE INDICATES THIS IS NOT A TRACTION TEST ****
"
5750  PRINT CHR$(128)
5760  PRINT LIN(1)
5770  INPUT "DO YOU STILL WANT A TRACTION VALUE (Y OR N)?",Rpl$
5780  IF Rpl$="N" THEN GOTO 6510
5790  PRINT PAGE
5800  PRINT "                    I M WORKING"
5810  MAT Div=ZER
5820  FOR I=1 TO L-1
5830  Div(1,I)=(D(I,4)-D(I,11))*88
5840  Div(2,I)=(D(I,8)-D(I,11))*88
5850  NEXT I
5860  FOR K=1 TO L-1
5870  Div(3,K)=D(K,2)
5880  Div(4,K)=D(K,6)
5890  NEXT K
5900  MAT SORT Div(1,*)
5910  Big1=Div(3,1)
5920  FOR J=2 TO L-1
5930  IF Div(3,J)<Big1 THEN GOTO 5960
5940  Big1=Div(3,J)
5950  Marker1=J
5960  NEXT J
5970  Count=0
5980  H=0
5990  Low=Div(1,Marker1)-44
6000  High=Div(1,Marker1)+44
6010  FOR I=1 TO L-1
6020  IF (Div(1,I)<Low) OR (Div(1,I)>High) THEN GOTO 6050
6030  Count=Count+1
6040  H=H+Div(3,I)
6050  NEXT I
6060  Hleft=H/Count
6070  MAT SORT Div(2,*)
6080  Big2=Div(4,1)
6090  FOR J=2 TO L-1
6100  IF Div(4,J)<Big2 THEN GOTO 6130
6110  Big2=Div(4,J)
6120  Marker2=J
6130  NEXT J
6140  Count=0
6150  H=0
6160  Low=Div(2,Marker2)-44
6170  High=Div(2,Marker2)+44
6180  FOR I=1 TO L-1
6190  IF (Div(2,I)<Low) OR (Div(2,I)>High) THEN GOTO 6220
6200  Count=Count+1
6210  H=H+Div(4,I)
6220  NEXT I
6230  Hright=H/Count
6240  PRINT PAGE
6250  INPUT "DO YOU WANT HARD COPY OR CRT OUTPUT (H OR C)?",Rpl$
6260  IF Rpl$="H" THEN GOTO 6290
6270  PRINTER IS 16
6280  GOTO 6300
6290  PRINTER IS 0
6300  INPUT "DO YOU WANT THE HEADING (DOCUMENTARY DATA)SUPRESSED (Y OR N)?",Rp$
```

```
6310  IF Rp$="Y" THEN GOTO 6390
6320  PRINT LIN(5)
6330  PRINT USING 6470;Loc$
6340  PRINT USING 6480;"FILE ";T$(2);T$(7);" TEST"
6350  PRINT USING 6480;"TIRE ";T$(5);T$(6);" psi"
6360  PRINT USING 6490;"MATERIAL: ";T$(8)
6370  PRINT USING 6490;T$(10);" CM THICKNESS"
6380  PRINT USING 6480;T$(12);" g cc";T$(11);" DEG C (AMBIENT)"
6390  PRINT LIN(3)
6400  PRINT "TRACTIVE EFFORT (WITHOUT RESISTANCE ADDED IN) "
6410  PRINT USING 6500;"  LEFT SIDE = ";Hleft
6420  PRINT USING 6500;" RIGHT SIDE = ";Hright
6430  PRINT LIN(2)
6440  PRINTER IS 16
6450  IF Rpl$="H" THEN GOTO 6470
6460  INPUT "PRESS CONT TO RESUME",Co
6470  IMAGE K
6480  IMAGE 2(K),4X,2(K)
6490  IMAGE 3(K)
6500  IMAGE 6(K)
6510  SUBEND
6520  SUB Plots
6530  OPTION BASE 1
6540  DIM Ylabel$[40],Xlabel$[40]
6550  COM Loc$[50],T$(14)[30],Dt$(*),D(11),Tc$,G$,SHORT D(*),M(*),D(*),Di
s(*),INTEGER L,Flag3
6560  Flag1=0
6570  Flag2=0
6580  PLOTTER IS 13,"GRAPHICS"
6590  PRINTER IS 16
6600  PRINT LIN(50)
6610  PRINT "                VERTICAL - 1"
6620  PRINT "          LONGITUDINAL - 2"
6630  PRINT "                    SIDE - 3"
6640  PRINT "                VELOCITY - 4"
6650  PRINT "      LONG. VERTICAL - 5"
6660  PRINT LIN(3)
6670  INPUT "CHOOSE VERTICAL AXIS FORCE CODE ",Y
6680  PRINT LIN(3)
6690  PRINT "                DISTANCE - 1"
6700  PRINT "                    TIME - 2"
6710  PRINT "                     DIV - 3"
6720  PRINT LIN(3)
6730  INPUT "CHOOSE HORIZONTAL AXIS CODE ",X
6740  ON Y GOTO 6750,6840,6930,7020,7110
6750  Var1=1
6760  Ylabel$="VERTICAL FORCE (LBS) "
6770  Var2=5
6780  Ymin=0
6790  Ymax=3000
6800  Ytic=50
6810  Yint=0
6820  Ymaj=10
6830  GOTO 7170
6840  Var1=2
6850  Ylabel$="LONGITUDINAL FORCE (LBS) "
6860  Var2=6
6870  Ymin=-200
6880  Ymax=1000
6890  Ytic=25
6900  Yint=-200
6910  Ymaj=8
6920  GOTO 7170
6930  Var1=3
6940  Ylabel$="SIDE FORCE (LBS)"
6950  Var2=7
6960  Ymin=-400
6970  Ymax=401
6980  Ytic=50
6990  Yint=-400
7000  Ymaj=4
7010  GOTO 7170
7020  Var1=4
7030  Ylabel$="WHEEL SPEED (MPH)"
7040  Var2=8
7050  Ymin=0
7060  Ymax=30
7070  Ytic=.5
7080  Yint=0
```

```
7090  Ymaj=6
7100  GOTO 7170
7110  Ymin=0
7120  Ymax=.0001
7130  Ytic=.05
7140  Yint=0
7150  Ymaj=2
7160  Ylabel$="LONGITUDINAL VERTICAL  FORCE"
7170  IF X=2 THEN GOTO 7580
7180  IF X=3 THEN GOTO 7660
7190  PRINT LIN(3)
7200  INPUT "DISTANCE TRAVELED BY VEHICLE (0) OR DISTANCE TRAVELED BY WHEEL (1) "
,P
7210  IF P=0 THEN GOTO 7340
7220  Flag1=Flag1+1
7230  IF Flag1>1 THEN GOTO 7450
7240  Dist(1,1)=0
7250  Dist(2,1)=0
7260  FOR I=2 TO L-1
7270  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,4)+D(I-1,4))/2)*((Milli(I)-Milli(I-1
))/1000)
7280  Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,8)+D(I-1,8))/2)*((Milli(I)-Milli(I-1
))/1000)
7290  NEXT I
7300  PRINT LIN(5),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
7310  PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
7320  INPUT "PRESS CONT TO RESUME",Dum
7330  GOTO 7450
7340  Flag2=Flag2+1
7350  IF Flag2>1 THEN GOTO 7440
7360  Dist(1,1)=0
7370  Dist(2,1)=0
7380  FOR I=2 TO L-1
7390  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((Milli(I)-Milli(I
-1))/1000)
7400  Dist(2,I)=Dist(1,I)
7410  NEXT I
7420  PRINT LIN(5),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
7430  INPUT "PRESS CONT TO RESUME",Dum
7440  IF P=0 THEN GOTO 7470
7450  Xlabel$="DISTANCE TRAVELED BY WHEEL (FT)"
7460  GOTO 7480
7470  Xlabel$="DISTANCE TRAVELED BY VEHICLE (FT)"
7480  Xmin=0
7490  Xmax=Dist(1,L-1)+10
7500  IF Dist(2,L-1)>Dist(1,L-1) THEN Xmax=Dist(2,L-1)+10
7510  Xint=0
7520  Xmaj=5
7530  Xtic=2
7540  IF Xmax>110 THEN Xtic=4
7550  IF Xmax>210 THEN Xtic=8
7560  IF Xmax>800 THEN Xtic=24
7570  GOTO 7930
7580  Xlabel$="TIME (SEC)"
7590  Xmin=0
7600  Xmax=INT(L/(1000/(Milli(5)-Milli(4))))+1
7610  Xtic=.5
7620  Xint=0
7630  Xmaj=2
7640  IF Xmax>16 THEN Xmaj=4
7650  GOTO 7930
7660  Xlabel$="DIFFERENTIAL INTERFACE VELOCITY (FT/SEC)"
7670  MAT Div=ZER
7680  IF Y<>5 THEN GOTO 7730
7690  Var1=1
7700  Var2=5
7710  Var3=2
7720  Var4=6
7730  FOR I=1 TO L-1
7740  Div(1,I)=(D(I,4)-D(I,11))*(5280/3600)
7750  IF Div(1,I)<0 THEN Div(1,I)=0
7760  Div(2,I)=(D(I,8)-D(I,11))*(5280/3600)
7770  IF Div(2,I)<0 THEN Div(2,I)=0
7780  Div(3,I)=D(I,Var1)
7790  Div(4,I)=D(I,Var2)
7800  IF Y<>5 THEN GOTO 7830
7810  Div(5,I)=D(I,Var3)
7820  Div(6,I)=D(I,Var4)
7830  NEXT I
```

```
7840 GOTO 7850
7850 Xmin=0
7860 MAT SORT Div(1,*)
7870 Xmax=Div(1,L-1)+5
7880 MAT SORT Div(2,*)
7890 IF Div(2,L-1)+5>Xma  THEN Xmax=Div(2,L-1)+5
7900 Xtic=.5
7910 Xmaj=10
7920 IF Xmax>50 THEN Xmaj=20
7930 Xr=ABS(Xmax-Xmin)
7940 Yr=ABS(Ymax-Ymin)
7950 PRINTER IS 16
7960 GRAPHICS
7970 SCALE Xmin-.3*Xr,Xmax+.2*Xr,Ymin-.3*Yr,Ymax+.2*Yr
7980 CLIP Xmin,Xmax,Ymin,Ymax
7990 AXES Xtic,Ytic,Xint,Yint,Xmaj,Ymaj,6
8000 LINE TYPE 6
8010 IF Y=5 THEN GOTO 8490
8020 MOVE Xmin,D(1,Var1)
8030 IF X=1 THEN GOTO 8090
8040 IF X=3 THEN GOTO 8130
8050 FOR I=1 TO L-1
8060 DRAW Milli(I)/1000,D(I,Var1)
8070 NEXT I
8080 GOTO 8180
8090 FOR I=1 TO L-2
8100 DRAW Dist(1,I+1),D(I,Var1)
8110 NEXT I
8120 GOTO 8180
8130 MAT SORT Div(1,*)
8140 FOR I=2 TO L-1
8150 IF (Div(1,I)=0) AND (Div(2,I)=0) THEN GOTO 8170
8160 DRAW Div(1,I),D(I,Var1)
8170 NEXT I
8180 LINE TYPE 1
8190 MOVE Xmin,D(1,Var2)
8200 IF X=1 THEN GOTO 8260
8210 IF X=3 THEN GOTO 8300
8220 FOR I=1 TO L-1
8230 DRAW Milli(I)/1000,D(I,Var2)
8240 NEXT I
8250 GOTO 8350
8260 FOR I=1 TO L-2
8270 DRAW Dist(2,I+1),D(I,Var2)
8280 NEXT I
8290 GOTO 8350
8300 MAT SORT Div(2,*)
8310 FOR I=2 TO L-1
8320 IF (Div(1,I)=0) AND (Div(2,I)=0) THEN GOTO 8340
8330 DRAW Div(2,I),D(I,Var2)
8340 NEXT I
8350 IF Y<>4 THEN GOTO 8480
8360 LINE TYPE 8
8370 MOVE Xmin,D(1,11)
8380 IF X=1 THEN GOTO 8440
8390 IF X=3 THEN GOTO 8470
8400 FOR I=1 TO L-1
8410 DRAW Milli(I)/1000,D(I,11)
8420 NEXT I
8430 GOTO 8470
8440 FOR I=1 TO L-2
8450 DRAW Dist(2,I+1),D(I,11)
8460 NEXT I
8470 LINE TYPE 1
8480 GOTO 8820
8490 MOVE Xmin,D(1,2)/D(1,1)
8500 IF X=1 THEN GOTO 8560
8510 IF X=3 THEN GOTO 8600
8520 FOR I=1 TO L-1
8530 DRAW Milli(I)/1000,D(I,2)/D(I,1)
8540 NEXT I
8550 GOTO 8650
8560 FOR I=1 TO L-2
8570 DRAW Dist(1,I+1),D(I,2)/D(I,1)
8580 NEXT I
8590 GOTO 8650
8600 MAT SORT Div(1,*)
8610 FOR I=2 TO L-1
8620 IF (Div(3,I)=0) AND (Div(4,I)=0) THEN GOTO 8640
8630 DRAW Div(1,I),Div(5,I)/Div(3,I)
```

```
8640  NEXT I
8650  LINE TYPE 1
8660  MOVE Xmin,D(1,6)/D(1,5)
8670  IF X=1 THEN GOTO 8730
8680  IF X=3 THEN GOTO 8770
8690  FOR I=1 TO L-1
8700  DRAW Milli(I)/1000,D(I,6)/D(I,5)
8710  NEXT I
8720  GOTO 8820
8730  FOR I=1 TO L-2
8740  DRAW Dist(2,I+1),D(I,6)/D(I,5)
8750  NEXT I
8760  GOTO 8820
8770  MAT SORT Div(2,*)
8780  FOR I=2 TO L-1
8790  IF (Div(3,I)=0) AND (Div(4,I)=0) THEN GOTO 8810
8800  DRAW Div(2,I),Div(6,I)/Div(4,I)
8810  NEXT I
8820  LORG 5
8830  FOR J=Xmin TO Xmax STEP Xtic*Xmaj
8840  MOVE J,Yint-.05*Yr
8850  LABEL J
8860  NEXT J
8870  FOR J=Ymin TO Ymax STEP Ytic*Ymaj
8880  MOVE Xint-.07*Xr,J
8890  LABEL J
8900  NEXT J
8910  LORG 4
8920  MOVE Xr/2,Ymin-.2*Yr
8930  LABEL Xlabel$
8940  DEG
8950  LDIR 90
8960  MOVE Xmin-.2*Xr,(Ymax+Ymin)/2
8970  LABEL Ylabel$
8980  LDIR 0
8990  CSIZE 2.9,.444
9000  Sp=Xmin+.15*Xr
9010  LORG 2
9020  MOVE Sp,Ymax-.01*Yr
9030  LABEL Loc$
9040  MOVE Sp,Ymax-.05*Yr
9050  LABEL "FLNM: ";T$(2)
9060  MOVE Sp,Ymax-.09*Yr
9070  LABEL "TIRE: ";T$(5)
9080  MOVE Sp,Ymax-.13*Yr
9090  LABEL T$(6);" psi"
9100  MOVE Sp,Ymax-.17*Yr
9110  LABEL T$(7);" TEST"
9120  Sp=5*Sp
9130  MOVE Sp,Ymax-.01*Yr
9140  LORG 8
9150  LABEL "LEFT WHEEL "
9160  MOVE Sp,Ymax-.01*Yr
9170  LINE TYPE 6
9180  LORG 2
9190  FOR I=.1 TO 1.4 STEP .4
9200  DRAW 6*(Xmin+.25*Xr)+I,Ymax-.01*Yr
9210  NEXT I
9220  MOVE Sp,Ymax-.05*Yr
9230  LINE TYPE 1
9240  LORG 8
9250  LABEL "RIGHT WHEEL "
9260  MOVE Sp,Ymax-.05*Yr
9270  LORG 2
9280  FOR I=.1 TO 1.4 STEP .4
9290  DRAW 6*(Xmin+.25*Xr)+I,Ymax-.05*Yr
9300  NEXT I
9310  IF Y<>4 THEN GOTO 9410
9320  MOVE Sp,Ymax-.09*Yr
9330  LORG 8
9340  LABEL "5th WHEEL "
9350  MOVE Sp,Ymax-.09*Yr
9360  LINE TYPE 8
9370  LORG 2
9380  FOR I=.1 TO 1.4 STEP .4
9390  DRAW 6*(Xmin+.25*Xr)+I,Ymax-.09*Yr
9400  NEXT I
9410  WAIT 5000
9420  INPUT "DO YOU WANT A HARD COPY (Y OR N)",Rpl$
9430  IF Rpl$<>"Y" THEN GOTO 9480
```

```
9440  PRINTER IS 0
9450  IMAGE 8,/////////
9460  PRINT USING 9450
9470  DUMP GRAPHICS
9480  EXIT GRAPHICS
9490  INPUT "DO YOU WANT ANOTHER PLOT WITH THIS FILE (Y OR N)",Rpl$
9500  IF Rpl$="Y" THEN GOTO 6580
9510  SUBEND
```

FILE NAME: READ-2:T15　　DATE : 09:20:08:14
MAIN PROGRAM

```
10    !          (READ-2)    TO RECOVER TEST DATA FROM
20    !                      TAPE AND MANIPULATE.
30    !                      WRITTEN BY G BLAISDELL
40    !                      MARCH 1981
50    !
60    !
70    !
80    OPTION BASE 1
90    DIM Zr(11),Scale(11),Dt$(1400)[22],Dt(11)
100   COM Loc$[50],T$(14)[30],Ylabel$[50],Xlabel$[50],SHORT Dio(6,1400),Dist(2,1
400),D(1400,11),INTEGER L,Mill(1400)
110   MASS STORAGE IS ":T14"
120   PRINTER IS 16
130   PRINT LIN(20)
140   INPUT "INPUT FILE NAME OF INTEREST ",Ft$
150   PRINT LIN(3)
160   ASSIGN #1 TO Ft$
170   READ #1;Loc$,T$(*)
180   READ #1;L
190   REDIM Dt$(L),Mill(L),Dist(2,L),D(L,11),Dio(6,L)
200   READ #1;Dt$(*),Mill(*)
210   INPUT "DO YOU WANT TO SEE THE AUXILIARY DATA (Y OR N)?",Rpl$
220   IF Rpl$<>"Y" THEN GOTO 310
230   INPUT "HARD COPY OR CRT (H OR C)",Rpl$
240   IF Rpl$="H" THEN GOTO 270
250   PRINTER IS 16
260   GOTO 280
270   PRINTER IS 0
280   CALL Auxdata
290   INPUT "PRESS CONT TO RESUME",Dum
300   PRINTER IS 16
310   ASSIGN #3 TO T$(14)
320   READ #3;Zr(*),Scale(*)
330   PRINT LIN(30),"                   **** DATA CONVERSION IN PROGRESS ****"
340 Convert: REM
350   FOR I=1 TO L-1
360   ENTER Dt$(I) USING "#,W";Dt(*)
370   FOR K=1 TO 11
380   D(I,K)=(BINCMP(Dt(K))-Zr(K))*Scale(K)
390   NEXT K
400   NEXT I
410   PRINT LIN(20)
420   PRINTER IS 16
430   PRINT "           NUMBER OF DATA POINTS TAKEN = ";L-1
440   PRINT "                             TO VIEW RAW DATA - 1"
450   PRINT "                                 TO PLOT DATA - 2"
460   PRINT "        TO RE-RUN PROGRAM WITH A NEW FILE - 3"
470   PRINT "                              TO STOP PROGRAM - 4"
480   PRINT "TO FIND AVERAGE MOTION RESISTANCE VALUE - 5"
490   PRINT "          TO FIND AVERAGE TRACTION VALUE - 6"
500   PRINT "                     TO INTEGRATE A CURVE - 7"
510   PRINT LIN(5)
520   INPUT "WHICH ROUTINE DO YOU WISH (ENTER NUMBER CODE)?",Rpl
530   IF Rpl=1 THEN CALL Rawdata
540   IF Rpl=2 THEN CALL Plots
550   IF Rpl=3 THEN GOTO 120
560   IF Rpl=4 THEN GOTO 600
570   IF (Rpl=5) OR (Rpl=6) THEN CALL Average
580   IF Rpl=7 THEN CALL Energy
590   GOTO 410
600   END
610   SUB Auxdata
620   OPTION BASE 1
630   COM Loc$[50],T$(14)[30],Ylabel$[50],Xlabel$[50],SHORT Dio(*),Dist(*),D(*),
INTEGER L,Mill(*)
```

```
640   IMAGE @,
650   PRINT USING 640
660   PRINT LIN(1),"FILE NAME:    ";T$(2)
670   PRINT LIN(1),"LOCATION:    ";Loc$
680   PRINT LIN(1),"AMBIENT TEMP:    ";T$(3);" DEG C"
690   PRINT LIN(1),"DATE AND TIME:    ";T$(4)
700   PRINT LIN(1),"TIRE CODE:    ";T$(5)
710   PRINT LIN(1),"TIRE INFLATION PRESS:    ";T$(6);" psi"
720   PRINT LIN(1),"TEST TYPE:    ";T$(7)
730   PRINT LIN(1),"CALIBRATION FILE NAME:    ";T$(14)
740   PRINT LIN(3),"TEST MATERIAL:    ";T$(8)
750   PRINT LIN(1),"TYPE(OR UNDERLYING SURFACE):    ";T$(9)
760   PRINT LIN(1),"DEPTH OR THICKNESS:    ";T$(10);" CM"
770   PRINT LIN(1),"MATERIAL TEMP:    ";T$(11);" DEG C",LIN(1)
780   IF T$(8)="SNOW" THEN PRINT "SNOW DENSITY:    ";T$(12);" G CC"
790   IF T$(8)="THAWING_SOIL" THEN PRINT "FROZEN LAYER THICK:    ";T$(12);" CM"
800   PRINT LIN(1),"SOLAR INPUT (CLOUD COVER, SHADE)    ";T$(13);"%"
810   SUBEND
820   SUB Rawdata
830   OPTION BASE 1
840   COM Loc$[50],T$(14)[30],Ylabel$[50],Xlabel$[50],SHORT Dim(*),Dist(*),D(*),
INTEGER L,Milli(*)
850   PRINTER IS 16
860   INPUT "HARD COPY OR ON CRT (H OR C)",Rpl$
870   IF Rpl$="H" THEN PRINTER IS 0
880   IMAGE 1X,"LV",5X,"LL",5X,"LS",5X,"LV1",7X,"RV",5X,"RL",5X,"RS",5X,"RV1",6X
,"SV1",4X,"Milli",
890   IMAGE #,4D,3X
900   IMAGE #,3X,4D,3X
910   IMAGE #,DD.D,3X
920   IMAGE #,2X,DD.D,3X
930   IMAGE #,6D
940   IMAGE /,20X
950   PRINT CHR$(27)&"H"
960   PRINT USING 880
970   PRINT CHR$(27)&"1"
980   FOR J=1 TO L-1
990   PRINT USING 940
1000  FOR K=1 TO 8
1010  IF K=5 THEN GOTO 1050
1020  IF (K=4) OR (K=8) THEN GOTO 1070
1030  PRINT USING 890;D(J,K)
1040  GOTO 1080
1050  PRINT USING 900;D(J,K)
1060  GOTO 1080
1070  PRINT USING 910;D(J,K)
1080  NEXT K
1090  PRINT USING 920;D(J,11)
1100  PRINT USING 930;Milli(J)
1110  NEXT J
1120  PRINT LIN(2)
1130  PRINT CHR$(27)&"m"
1140  SUBEND
1150  SUB Average
1160  OPTION BASE 1
1170  DIM Ave(8),A(L+1),Prcnt(8)
1180  COM Loc$[50],T$(14)[30],Ylabel$[50],Xlabel$[50],SHORT Dim(*),Dist(*),D(*)
,INTEGER L,Milli(*)
1190  MAT Ave=ZER
1200  Mrk=0
1210  PRINTER IS 16
1220  PRINT LIN(20),"       VERTICAL - 1"
1230  PRINT "  LONGITUDINAL - 2"
1240  PRINT "           SIDE - 3"
1250  PRINT "       VELOCITY - 4"
1260  PRINT "    LONG./VERT. - 5"
1270  PRINT LIN(5)
1280  INPUT "CHOOSE CODE FOR CHANNEL TO BE AVERAGED ",Ch
1290  IF Ch<>5 THEN GOTO 1320
1300  Ch=2
1310  Mrk=1
1320  PRINT LIN(20)
1330  PRINT "       WHAT PERCENT OF THE DATA POINTS DO YOU WANT AVERAGED ?"
1340  PRINT LIN(2),"ANYTHING LESS THAN 100% WILL AVERAGE THE UPPER (ABSOLUTE VAL
UE) PERCENT CHOSEN"
1350  INPUT Prcnt(Ch)
1360  Prcnt(Ch+4)=Prcnt(Ch)
1370  PRINT LIN(20),TAB(30),"I'M WORKING"
1380  PRINT LIN(5)
1390  FOR G=Ch TO Ch+4 STEP 4
```

```
1400  FOR H=1 TO L-1
1410  A(H)=D(H,G)
1420  IF Mrk=1 THEN A(H)=D(H,G)-D(H,G-1)
1430  NEXT H
1440  IF Prcnt=100 THEN GOTO 1560
1450  MAT SORT A
1460  Sum2=0
1470  FOR P=1 TO L/20
1480  Sum2=Sum2+A(P)
1490  NEXT P
1500  Aver=Sum2/(L/20)
1510  IF Aver>0 THEN GOTO 1560
1520  FOR H2=1 TO L-1
1530  A(H2)=ABS(A(H2))
1540  NEXT H2
1550  MAT SORT A
1560  Sum1=0
1570  Count=INT(Prcnt(Ch)/100*(L-1))
1580  FOR P=L-Count TO L-1
1590  Sum1=Sum1+A(P)
1600  NEXT P
1610  Ave(G)=Sum1/Count
1620  NEXT G
1630  PRINT LIN(20)
1640  INPUT "     DO YOU WANT TO CALCULATE ANY OTHER AVERAGES (Y OR N)?",Over$
1650  IF Over$="Y" THEN GOTO 1210
1660  INPUT "DO YOU WANT THE OUTPUT ON THE CRT OR A HARD COPY (C OR H)?",R$
1670  IF R$<>"H" THEN GOTO 1700
1680  PRINTER IS 0
1690  GOTO 1710
1700  PRINTER IS 16
1710  INPUT "DO YOU WANT TO SUPRESS THE HEADING (DOCUMENTARY DATA) (Y OR N)?",Rp
$
1720  IF Rp$="Y" THEN GOTO 1790
1730  PRINT USING 1910;Loc$
1740  PRINT USING 1920;"FILE ";T$(2);T$(7);" TEST"
1750  PRINT USING 1920;"TIPE ";T$(5);T$(6);" psi"
1760  PRINT USING 1930;"MATERIAL: ";T$(8)
1770  PRINT USING 1930;T$(10);" CM THICKNESS"
1780  PRINT USING 1920;T$(12);" g/cc";T$(11);" DEG C (AMBIENT)"
1790  PRINT LIN(2)
1800  FOR I=1 TO 8
1810  IF Ave(I)=0 THEN GOTO 1950
1820  Sd$="LEFT "
1830  IF I>4 THEN Sd$="RIGHT "
1840  Unit$=" LBS"
1850  IF (I=4) OR (I=8) THEN Unit$=" MPH"
1860  IF (I=1) OR (I=5) THEN Ch$="VERTICAL"
1870  IF (I=2) OR (I=6) THEN Ch$="LONGITUDINAL"
1880  IF (I=3) OR (I=7) THEN Ch$="SIDE"
1890  IF (I=4) OR (I=8) THEN Ch$="VELOCITY"
1900  PRINT USING 1940;"AVERAGE OF UPPER ";Prcnt(I);"% OF DATA - ";Sd$;Ch$;" - "
;Ave(I);Unit$
1910  IMAGE K
1920  IMAGE 2(K),4X,2(K)
1930  IMAGE 3(K)
1940  IMAGE /K,DDD.D,4(K),DDDD.DDDD,K
1950  NEXT I
1960  IF P$="H" THEN GOTO 1990
1970  PRINT LIN(5)
1980  INPUT " PRESS CONT TO RESUME",Dum
1990  SUBEND
2000  SUB Plots
2010  OPTION BASE 1
2020  COM Loc$[50],T$(14)[30],Ylabel$[50],Xlabel$[50],SHORT Div(*),Dist(*),D(*),
INTEGER L,Mill(*)
2030  Flag1=0
2040  Flag2=0
2050  PLOTTER IS 13,"GRAPHICS"
2060  PRINTER IS 16
2070  PRINT LIN(50)
2080  PRINT "              VERTICAL - 1"
2090  PRINT "          LONGITUDINAL - 2"
2100  PRINT "                  SIDE - 3"
2110  PRINT "              VELOCITY - 4"
2120  PRINT "        LONG./VERTICAL - 5"
2130  PRINT LIN(3)
2140  INPUT "CHOOSE VERTICAL AXIS FORCE CODE ",Y
2150  PRINT LIN(3)
```

```
2160  PRINT "           DISTANCE - 1"
2170  PRINT "               TIME - 2"
2180  PRINT "                DIV - 3"
2190  PRINT LIN(3)
2200  INPUT "CHOOSE HORIZONTAL AXIS CODE ",X
2210  ON Y GOTO 2220,2310,2400,2490,2580
2220  Var1=1
2230  Ylabel$="VERTICAL FORCE (LBS) "
2240  Var2=5
2250  Ymin=0
2260  Ymax=3000
2270  Ytic=50
2280  Yint=0
2290  Ymaj=10
2300  GOTO 2640
2310  Var1=2
2320  Ylabel$="LONGITUDINAL FORCE (LBS) "
2330  Var2=6
2340  Ymin=-200
2350  Ymax=1000
2360  Ytic=25
2370  Yint=-200
2380  Ymaj=8
2390  GOTO 2640
2400  Var1=3
2410  Ylabel$="SIDE FORCE (LBS)"
2420  Var2=7
2430  Ymin=-800
2440  Ymax=801
2450  Ytic=50
2460  Yint=-800
2470  Ymaj=4
2480  GOTO 2640
2490  Var1=4
2500  Ylabel$="WHEEL SPEED (MPH)"
2510  Var2=8
2520  Ymin=0
2530  Ymax=30
2540  Ytic=.5
2550  Yint=0
2560  Ymaj=6
2570  GOTO 2640
2580  Ymin=0
2590  Ymax=.8001
2600  Ytic=.05
2610  Yint=0
2620  Ymaj=2
2630  Ylabel$="LONGITUDINAL/VERTICAL  FORCE"
2640  IF X=2 THEN GOTO 3030
2650  IF X=3 THEN GOTO 3110
2660  PRINT LIN(3)
2670  INPUT "DISTANCE TRAVELED BY VEHICLE (0) OR DISTANCE TRAVELED BY WHEEL (1)"
,R
2680  IF R=0 THEN GOTO 2810
2690  Flag1=Flag1+1
2700  IF Flag1>1 THEN GOTO 2910
2710  Dist(1,1)=0
2720  Dist(2,1)=0
2730  FOR I=2 TO L-1
2740  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,4)+D(I-1,4))/2)*((Mill(I)-Mill(I-1
))/1000)
2750  Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,8)+D(I-1,8))/2)*((Mill(I)-Mill(I-1
))/1000)
2760  NEXT I
2770  PRINT LIN(5),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
2780  PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
2790  INPUT "PRESS CONT TO RESUME",Dum
2800  GOTO 2920
2810  Flag2=Flag2+1
2820  IF Flag2>1 THEN GOTO 2910
2830  Dist(1,1)=0
2840  Dist(2,1)=0
2850  FOR I=2 TO L-1
2860  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((Mill(I)-Mill(I
-1))/1000)
2870  Dist(2,I)=Dist(1,I)
2880  NEXT I
2890  PRINT LIN(5),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
2900  INPUT "PRESS CONT TO RESUME",Dum
2910  IF R=0 THEN GOTO 2940
```

```
2920  Xlabel$="DISTANCE TRAVELED BY WHEEL (FT)"
2930  GOTO 2950
2940  Xlabel$="DISTANCE TRAVELED BY VEHICLE (FT)"
2950  Xmin=0
2960  Xmax=Dist(1,L-1)+10
2970  IF Dist(2,L-1)>Dist(1,L-1) THEN Xmax=Dist(2,L-1)+10
2980  Xint=0
2990  Xmaj=5
3000  Xtic=2
3010  IF Xmax>110 THEN Xtic=4
3020  GOTO 3380
3030  Xlabel$="TIME (SEC)"
3040  Xmin=0
3050  Xmax=INT(L/(1000/(Milli(5)-Milli(4))))+1
3060  Xtic=.5
3070  Xint=0
3080  Xmaj=2
3090  IF Xmax>16 THEN Xmaj=4
3100  GOTO 3380
3110  Xlabel$="DIFFERENTIAL INTERFACE VELOCITY (FT/SEC)"
3120  MAT Div=ZER
3130  IF Y<>5 THEN GOTO 3180
3140  Var1=1
3150  Var2=5
3160  Var3=2
3170  Var4=6
3180  FOR I=1 TO L-1
3190  Div(1,I)=(D(I,4)-D(I,11))*(5280/3600)
3200  IF Div(1,I)<0 THEN Div(1,I)=0
3210  Div(2,I)=(D(I,8)-D(I,11))*(5280/3600)
3220  IF Div(2,I)<0 THEN Div(2,I)=0
3230  Div(3,I)=D(I,Var1)
3240  Div(4,I)=D(I,Var2)
3250  IF Y<>5 THEN GOTO 3280
3260  Div(5,I)=D(I,Var3)
3270  Div(6,I)=D(I,Var4)
3280  NEXT I
3290  GOTO 3300
3300  Xmin=0
3310  MAT SORT Div(1,*)
3320  Xmax=Div(1,L-1)+5
3330  MAT SORT Div(2,*)
3340  IF Div(2,L-1)+5>Xmax THEN Xmax=Div(2,L-1)+5
3350  Xtic=.5
3360  Xmaj=10
3370  IF Xmax>50 THEN Xmaj=20
3380  Xr=ABS(Xmax-Xmin)
3390  Yr=ABS(Ymax-Ymin)
3400  PRINTER IS 16
3410  GRAPHICS
3420  SCALE Xmin-.3*Xr,Xmax+.2*Xr,Ymin-.3*Yr,Ymax+.2*Yr
3430  CLIP Xmin,Xmax,Ymin,Ymax
3440  AXES Xtic,Ytic,Xint,Yint,Xmaj,Ymaj,6
3450  LINE TYPE 6
3460  IF Y=5 THEN GOTO 3940
3470  MOVE Xmin,D(1,Var1)
3480  IF X=1 THEN GOTO 3540
3490  IF X=3 THEN GOTO 3580
3500  FOR I=1 TO L-1
3510  DRAW Milli(I)/1000,D(I,Var1)
3520  NEXT I
3530  GOTO 3630
3540  FOR I=1 TO L-2
3550  DRAW Dist(1,I+1),D(I,Var1)
3560  NEXT I
3570  GOTO 3630
3580  MAT SORT Div(1,*)
3590  FOR I=2 TO L-1
3600  IF (Div(1,I)=0) AND (Div(2,I)=0) THEN GOTO 3620
3610  DRAW Div(1,I),D(I,Var1)
3620  NEXT I
3630  LINE TYPE 1
3640  MOVE Xmin,D(1,Var2)
3650  IF X=1 THEN GOTO 3710
3660  IF X=3 THEN GOTO 3750
3670  FOR I=1 TO L-1
3680  DRAW Milli(I)/1000,D(I,Var2)
3690  NEXT I
3700  GOTO 3800
3710  FOR I=1 TO L-2
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3720 DRAW Dist(2,I+1),D(I,Var2)
3730 NEXT I
3740 GOTO 3800
3750 MAT SORT Div(2,*)
3760 FOR I=2 TO L-1
3770 IF (Div(1,I)=0) AND (Div(2,I)=0) THEN GOTO 3790
3780 DRAW Div(2,I),D(I,Var2)
3790 NEXT I
3800 IF Y<>4 THEN GOTO 3930
3810 LINE TYPE 8
3820 MOVE Xmin,D(1,11)
3830 IF X=1 THEN GOTO 3890
3840 IF X=3 THEN GOTO 3920
3850 FOR I=1 TO L-1
3860 DRAW Milli(I)/1000,D(I,11)
3870 NEXT I
3880 GOTO 3920
3890 FOR I=1 TO L-2
3900 DRAW Dist(2,I+1),D(I,11)
3910 NEXT I
3920 LINE TYPE 1
3930 GOTO 4270
3940 MOVE Xmin,D(1,2)/D(1,1)
3950 IF X=1 THEN GOTO 4010
3960 IF X=3 THEN GOTO 4050
3970 FOR I=1 TO L-1
3980 DRAW Milli(I)/1000,D(I,2)/D(I,1)
3990 NEXT I
4000 GOTO 4100
4010 FOR I=1 TO L-2
4020 DRAW Dist(1,I+1),D(I,2)/D(I,1)
4030 NEXT I
4040 GOTO 4100
4050 MAT SORT Div(1,*)
4060 FOR I=2 TO L-1
4070 IF (Div(3,I)=0) AND (Div(4,I)=0) THEN GOTO 4090
4080 DRAW Div(1,I),Div(5,I)/Div(3,I)
4090 NEXT I
4100 LINE TYPE 1
4110 MOVE Xmin,D(1,6)/D(1,5)
4120 IF X=1 THEN GOTO 4180
4130 IF X=3 THEN GOTO 4220
4140 FOR I=1 TO L-1
4150 DRAW Milli(I)/1000,D(I,6)/D(I,5)
4160 NEXT I
4170 GOTO 4270
4180 FOR I=1 TO L-2
4190 DRAW Dist(2,I+1),D(I,6)/D(I,5)
4200 NEXT I
4210 GOTO 4270
4220 MAT SORT Div(2,*)
4230 FOR I=2 TO L-1
4240 IF (Div(3,I)=0) AND (Div(4,I)=0) THEN GOTO 4260
4250 DRAW Div(2,I),Div(6,I)/Div(4,I)
4260 NEXT I
4270 LORG 5
4280 FOR J=Xmin TO Xmax STEP Xtic*Xmaj
4290 MOVE J,Yint-.05*Yr
4300 LABEL J
4310 NEXT J
4320 FOR J=Ymin TO Ymax STEP Ytic*Ymaj
4330 MOVE Xint-.07*Xr,J
4340 LABEL J
4350 NEXT J
4360 LORG 4
4370 MOVE Xr/2,Ymin-.2*Yr
4380 LABEL Xlabel$
4390 DEG
4400 LDIR 90
4410 MOVE Xmin-.2*Xr,(Ymax+Ymin)/2
4420 LABEL Ylabel$
4430 LDIR 0
4440 CSIZE 2.9,.444
4450 Sp=Xmin+.15*Xr
4460 LORG 2
4470 MOVE Sp,Ymax-.01*Yr
4480 LABEL Loc$
4490 MOVE Sp,Ymax-.05*Yr
4500 LABEL "FLNM: ";T$(2)
4510 MOVE Sp,Ymax-.09*Yr
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4520  LABEL "TIRE: ";T$(5)
4530  MOVE Sp,Ymax-.13*Yr
4540  LABEL T$(6);" psi"
4550  MOVE Sp,Ymax-.17*Yr
4560  LABEL T$(7);" TEST"
4570  Sp=5*Sp
4580  MOVE Sp,Ymax-.01*Yr
4590  LORG 8
4600  LABEL "LEFT WHEEL "
4610  MOVE Sp,Ymax-.01*Yr
4620  LINE TYPE 6
4630  LORG 2
4640  FOR I=.1 TO 1.4 STEP .4
4650  DRAW 6*(Xmin+.25*Xr)+I,Ymax-.01*Yr
4660  NEXT I
4670  MOVE Sp,Ymax-.05*Yr
4680  LINE TYPE 1
4690  LORG 8
4700  LABEL "RIGHT WHEEL "
4710  MOVE Sp,Ymax-.05*Yr
4720  LORG 2
4730  FOR I=.1 TO 1.4 STEP .4
4740  DRAW 6*(Xmin+.25*Xr)+I,Ymax-.05*Yr
4750  NEXT I
4760  IF Y<4 THEN GOTO 4860
4770  MOVE Sp,Ymax-.09*Yr
4780  LORG 8
4790  LABEL "5th WHEEL "
4800  MOVE Sp,Ymax-.09*Yr
4810  LINE TYPE 8
4820  LORG 2
4830  FOR I=.1 TO 1.4 STEP .4
4840  DRAW 6*(Xmin+.25*Xr)+I,Ymax-.09*Yr
4850  NEXT I
4860  WAIT 5000
4870  INPUT "DO YOU WANT A HARD COPY (Y OR N)",Rpl$
4880  IF Rpl$<>"Y" THEN GOTO 4930
4890  PRINTER IS 0
4900  IMAGE 0,/////,///
4910  PRINT USING 4900
4920  DUMP GRAPHICS
4930  EXIT GRAPHICS
4940  INPUT "DO YOU WANT ANOTHER PLOT WITH THIS FILE (Y OR N)",Rpl$
4950  IF Rpl$="Y" THEN GOTO 2050
4960  SUBEND
4970  SUB Energy
4980  OPTION BASE 1
4990  DIM Energy(2,L)
5000  COM Loc$[50],T$(14)[30],Ylabel$[50],Xlabel$[50],SHORT Diff(*),Dist(*),D(*),
INTEGER L,Milli(*)
5010  IF T$(7)="TRACTION" THEN GOTO 5080
5020  PRINT TAB(10),CHR$(132);"*** FILE INDICATES THIS IS NOT A TRACTION TEST **
*"
5030  PRINT CHR$(128)
5040  PRINT LIN(2),"DO YOU STILL WANT AN INTEGRATION "
5050  PRINT TAB(30),"(Y OR N)"
5060  INPUT R$
5070  IF R$<>"Y" THEN GOTO 5820
5080  PRINT LIN(25)
5090  PRINT "                LONGITUDINAL FORCE VS WHEEL DISTANCE - 1"
5100  PRINT "              LONGITUDINAL FORCE VS VEHICLE DISTANCE - 2"
5110  PRINT "   LONGITUDINAL/VERTICAL FORCE VS WHEEL DISTANCE - 3"
5120  PRINT " LONGITUDINAL/VERTICAL FORCE VS VEHICLE DISTANCE - 4"
5130  PRINT LIN(3)
5140  INPUT "CHOOSE PLOT TO BE INTEGRATED",Intg
5150  INPUT "DO YOU WANT THE OUTPUT ON THE CRT (C) OR A HARD COPY (H)?",Rpl$
5160  PRINT LIN(20),TAB(30),"I'M WORKING"
5170  PRINT LIN(5)
5180  IF Rpl$<>"H" THEN GOTO 5210
5190  PRINTER IS 0
5200  GOTO 5220
5210  PRINTER IS 16
5220  PRINT LIN(2)
5230  ON Intg GOTO 5240,5370,5490,5620
5240  MAT Dist=ZER
5250  MAT Energy=ZER
5260  FOR I=2 TO L-1
5270  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,4)+D(I-1,4))/2)*((Milli(I)-Milli(I-1
))/1000)
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5280  Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,8)+D(I-1,8))/2)*((Mill(I)-Mill(I-1
))/1000)
5290  NEXT I
5300  PRINT LIN(2),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5310  PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
5320  FOR I=2 TO L-1
5330  Energy(1,I)=Energy(1,I-1)+(D(I,2)+D(I-1,2))/2*(Dist(1,I)-Dist(1,I-1))
5340  Energy(2,I)=Energy(2,I-1)+(D(I,6)+D(I-1,6))/2*(Dist(2,I)-Dist(2,I-1))
5350  NEXT I
5360  GOTO 5730
5370  MAT Dist=ZER
5380  MAT Energy=ZER
5390  FOR I=2 TO L-1
5400  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((Mill(I)-Mill(I
-1))/1000)
5410  Dist(2,I)=Dist(1,I)
5420  NEXT I
5430  PRINT LIN(2),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5440  FOR I=2 TO L-1
5450  Energy(1,I)=Energy(1,I-1)+(D(I,2)+D(I-1,2))/2*(Dist(1,I)-Dist(1,I-1))
5460  Energy(2,I)=Energy(2,I-1)+(D(I,6)+D(I-1,6))/2*(Dist(2,I)-Dist(2,I-1))
5470  NEXT I
5480  GOTO 5730
5490  MAT Dist=ZER
5500  MAT Energy=ZER
5510  FOR I=2 TO L-1
5520  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,4)+D(I-1,4))/2)*((Mill(I)-Mill(I-1
))/1000)
5530  Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,8)+D(I-1,8))/2)*((Mill(I)-Mill(I-1
))/1000)
5540  NEXT I
5550  PRINT LIN(2),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5560  PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
5570  FOR I=2 TO L-1
5580  Energy(1,I)=Energy(1,I-1)+(D(I,2)/D(I,1)+D(I-1,2)/D(I-1,1))/2*(Dist(1,I)-D
ist(1,I-1))
5590  Energy(2,I)=Energy(2,I-1)+(D(I,6)/D(I,5)+D(I-1,6)/D(I-1,5))/2*(Dist(2,I)-D
ist(2,I-1))
5600  NEXT I
5610  GOTO 5730
5620  MAT Dist=ZER
5630  MAT Energy=ZER
5640  FOR I=2 TO L-1
5650  Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((Mill(I)-Mill(I
-1))/1000)
5660  Dist(2,I)=Dist(1,I)
5670  NEXT I
5680  PRINT LIN(2),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5690  FOR I=2 TO L-1
5700  Energy(1,I)=Energy(1,I-1)+(D(I,2)/D(I,1)+D(I-1,2)/D(I-1,1))/2*(Dist(1,I)-D
ist(1,I-1))
5710  Energy(2,I)=Energy(2,I-1)+(D(I,6)/D(I,5)+D(I-1,6)/D(I-1,5))/2*(Dist(2,I)-D
ist(2,I-1))
5720  NEXT I
5730  IMAGE /K,DDDDDDDDD.D,K
5740  Label$=" FT"
5750  IF (Intg=1) OR (Intg=2) THEN Label$=" FT-LBS"
5760  PRINT USING 5730;"LEFT WHEEL ENERGY  = ";Energy(1,L-1);Label$
5770  PRINT USING 5730;"RIGHT WHEEL ENERGY = ";Energy(2,L-1);Label$
5780  PRINTER IS 16
5790  INPUT "DO YOU WANT TO INTEGRATE ANY OTHER CURVES (Y OR N)?",Rpl$
5800  IF Rpl$="Y" THEN GOTO 5080
5810  INPUT "PRESS CONT TO RESUME",Dum
5820  SUBEND
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